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THE MONTREAL FILTRATION WORKS.

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[*Read September 19, 1928.*]

Three years ago a paper was presented before the New England Water Works Association on the Montreal Filtration Works.‡

ORIGINAL PLANT.

The plant as originally designed by Messrs. Hering and Fuller and constructed under their supervision included the following:

Low-lift pumping station; capacity, 150 m.g.d. (Imp.)
16 Pre-filters; nominal combined capacity, 50 m.g.d. (Imp.); unit sand area, 1 200 sq. ft.
16 Final filters; nominal combined capacity, 50 m.g.d. (Imp.); unit sand area, $\frac{3}{8}$ acre.
Filtered-water Basin No. 1; capacity $6\frac{1}{4}$ m.g. (Imp.) and such conduits, gatehouses and equipment to make the installation complete and ready for operation.

Construction work was started in 1911, but on account of numerous delays the plant was not completed and placed in service until April, 1918.

The cost of this plant complete exclusive of land was $1 408 300 or $28 000 per m.g.d. (Imp.) at nominal rating.

The original scheme was to have the pre-filters and final filters operated together as one plant, *i.e.* double filtration, without the use of coagulant, but the conduits and gatehouses were designed to permit of the pre-filters and final filters being operated as separate plants or as partially combined plants. This foresight on the part of the designers of the original plant has been amply justified.

In 1910 the average daily output of the municipal water-works plant was 38 m.g., and the filter plant was designed for 50 m.g.d. nominal capacity which would permit of a 30 per cent. increased output. In 1918, the first year of operation, the required output of filtered water was 60 m.g.d. (Imp.)

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‡JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION, Vol. 39, 1925, p. 213. This paper described quite fully the water-supply system of the city of Montreal, the filtration works, and the main pumping station, so that in this paper it is only necessary to briefly mention such features of the original plant as will help to complete the description of the plant with its recent extensions.

or 20 per cent. above the designed nominal capacity of the plant. The demands for filtered water increased rapidly in succeeding years, and last year, *i.e.* 1927, the daily output was 85 m.g. (Imp.) or 70 per cent. in excess of the designed nominal capacity of the plant. During July, 1928, the average daily output was 92 m.g. and the maximum day's output was 97.6 m.g. or 94 per cent. in excess of the designed nominal capacity of the plant.

Notwithstanding this excessive overload on the filters, the plant has run continuously and has at all times delivered to the citizens of Montreal a water satisfactory in all respects.

Filter Extension.

The need for additional filters has been recognized for several years, but construction was delayed until adequate pumping capacity was provided by the completion of the new low-level pumping station. This contains six 30-m.g.d. pumping units with provision for extending the building to house six additional pumps of the same capacity.

To provide ample storage of filtered water, Filtered-water Basin No. 2 was constructed between Filtered-water Basin No. 1 and the new low-level pumping station. This basin having a capacity of 20 m.g. (Imp.) was constructed at a cost of $624 400.

During the construction of the new low-level pumping station and Filtered-water Basin No. 2, several schemes for filter extension were studied and estimates of cost compared. The satisfactory operation of the existing pre-filters and the comparatively low cost of constructing 32 additional filters, similar in size, arrangement and general design, above the roof of Filtered-water Basin No. 1 resulted in this plan being adopted. These 32 additional filters will have a combined nominal capacity of 100 m.g.d. (Imp.) which added to the original plant will make the total nominal capacity of the plant 150 m.g.d. (Imp.) and equals the nominal capacity of the new low-level pumping station.

In all probability, the original 16 pre-filters and 16 final filters will be operated as a combined plant and the 32 new filters will be operated as rapid sand filters and discharge independently into Filtered-water Basin No. 2.

The cost of this work now nearing completion may be subdivided as follows:

Earthwork, filters, buildings, etc.	$360 000.00
C. I. piping, gate valves and sluice gates	213 958.00
Air piping and small piping	17 880.00
Filter rate controllers	40 000.00
Filter operating tables and gages	66 641.00
Filter strainer- and air-system	67 867.00
Wash-water gutters	17 203.00
Filter sand and gravel	69 038.00

Gages, telephone system and signal system	$12 129.00
Chlorination building and equipment	24 000.00
Park lighting-system	14 303.00
Fence and gateways	46 000.00
Greenhouse, trees and shrubs	11 500.00
Miscellaneous work and equipment	48 621.00
TOTAL	$1 009 140.00

This makes the cost of the filter extension $10 000 per m.g.d. (Imp.) nominal designed output. The total cost of the filtration works is therefore $2 417 440 which on the nominal designed capacity, 150 m.g.d. (Imp.), makes the construction cost $16 116 per m.g.d.

CONSTRUCTION AND EQUIPMENT FEATURES.

Filter Strainer- and Air-System. The strainer-systems in the original pre-filters and the new rapid sand filters are identical and furnished by the Roberts Filter Mfg. Co. They consist of C. I. manifolds and $1\frac{3}{4}$-in. C. I. pipe laterals on 6-in. center, approximately 6 ft. in length with two $\frac{3}{16}$-in. bronze orifices for each 6 in. of lateral.

The system is for both air and water wash. The air is supplied from a rotary Root blower having a capacity of 5 000 cu. ft. of free air per minute against a pressure of 5 lb. per sq. in., which gives approximately 4 cu. ft. of air per minute for each square foot of sand surface in a filter.

The wash water is supplied from a wash-water tank and is delivered at the rate of approximately $8\frac{1}{2}$ Imperial g.p.m. for each square foot of sand surface.

Filter Sand and Gravel. The filter gravel in the original pre-filters and in the new filters is deposited in four layers of specified screened sizes to a total combined depth of 15 in. The filter sand is 30 in. in depth. In the original pre-filters, this sand had an effective size of between 0.50 mm. and 0.60 mm. and a uniformity coefficient of about 1.65. In the new filters, the effective size of the sand varies from 0.40 mm. to 0.50 mm., and the uniformity coefficient is about 1.68. In the original final filters, 12 in. of graded gravel are placed in four layers and 27 in. of sand having an effective size of from 0.25 mm. to 0.35 mm.

Rate Controllers. Each of the original pre-filters and final filters was equipped with controllers of the Earl type with a master controller to regulate the entire system. These controllers have given satisfaction in all respects.

The new filters will be equipped with controllers furnished by the Builders Iron Foundry and will work in conjunction with their new pendulum diaphragm units for loss of head and rate of flow below and their new loss of head and rate of flow gages on the operating tables in the filter galleries. These controllers are also provided with master control.

Operating Tables. All operating tables in the galleries are of the piano type and constructed of gray marble which gives an attractive contrast with the red tile floor of the gallery.

Clock and Signal System. The wash-water pumps, wash-water tank and piping system do not have sufficient capacity to permit of more than one filter being washed at the same time. This makes it necessary for the filter operator in one gallery to be kept informed, not only as to the supply of the water available in the wash-water tank, but also as to whether or not filter washing is in progress in either of the other two galleries. It is expected that the clock and signal system will systemize the filter washing and prevent interference in the work of filter operators in the three filter galleries. This system includes the master clock and signal lights in the superintendent's office, and secondary clocks and signal lights in each of the three galleries, the entire system being electrically operated.

The system is so arranged that when the influent valve to any filter is closed by operating a handle on the operating table, a light will automatically show at the master and secondary clocks and continue to show until the influent valve is again opened; thus completing the cycle of a filter wash. There is also a switch on each operating table whereby the automatic lighting of the signal from that particular table is cut out, if, for any reason, the influent valve is operated for any purpose except the washing of the filter. The lights to indicate when filters are being washed are three in number and show *red* for filters in Gallery No. 1, *yellow* for filters in Gallery No. 2, and *green* for filters in Gallery No. 3.

The master clock in the superintendent's office is of the wall type with the three signal lights incorporated in the bottom of the case. The secondary clocks, suspended from the ceiling in the center of each operating gallery, are double-faced with illuminated dials so as to be easily read from the far ends of the gallery. The three signal lights are incorporated in the bottom of the bronze case. The depth of water in the wash-water tank is also indicated on the clock in the following manner:

Immediately concentric with the outside of the dial is a ring which is automatically illuminated to show the depth of water in the tank. The total depth of the wash-water tank is 12 ft., which corresponds to the hour figures on the clock dial. Therefore, by reading clock-wise, the hour figure at the end of the band of illumination will indicate the depth of the water in the tank.

Inter-phone System. To still further assist the operators in the performance of their work, an inter-communicating telephone system will be installed. Telephone sets will be provided in the superintendent's office, clerk's office, in each of the three filter operators' booths, at the electrical operator's desk in the pumping station, in the chlorination building and such other places as are deemed necessary.

Water-level Controllers. In Galleries Nos. 2 and 3, the discharge from each filter enters a gallery effluent-conduit which extends the entire length

of the pipe gallery and passes through a gatehouse into a conduit which discharges into the filtered-water basin.

The water level in the filtered-water basin is several feet lower than the invert of this gallery effluent-conduit. With water in the filtered-water basin at a low level and with a low rate of discharge in the gallery effluent-conduit, the discharge ends of the filter effluent-pipes would not be submerged, thus allowing entrance of air to the bottom of the filter beds, when the water level in the filtered-water basin was raised or the discharge through the gallery effluent-conduit was increased. To prevent any possibility of air entering the filters in this manner, a water-level controller will be installed in the gatehouse, at the end of each pipe gallery.

A float, operating a pilot valve connected to the piping of the hydraulic cylinder of a 60 in. x 60 in. sluice gate, controlling the discharge of the gallery effluent-conduit, will automatically maintain the water level in the gallery effluent-conduit in such manner as to keep the filter effluent-pipes submerged, and not decrease the available loss of head in the filters.

Chlorination Building and Equipment. This building is above the chamber through which all filtered water passes on its way to Filtered-water Basin No. 2 and the new low-level pumping station. This chamber is provided with baffle walls to obtain a thorough mixing of the chlorine dose with the filtered water.

The central portion of the floor of the chlorination building is depressed to permit of the installation of weighing scales with platforms level with the operating floor. The platforms of these weighing scales are of such size as to allow 12 cylinders of liquid chlorine to be placed thereon. Each cylinder is connected by piping to a manifold which leads to the chlorination control table. This table is of gray marble, of the piano type, similar in design to the filter operating-tables.

This table houses Duriron ejectors and distributors. The suction produced by water under pressure passing through these ejectors draws the chlorine from the cylinders on the platform scales and discharges it into the baffled current of filtered water in the chamber below. On the top of the operating table are located the necessary gages and valve controls and also apparatus for testing the water after chlorination.

The building is of sufficient size to permit of the entrance of a truck loaded with cylinders or drums of liquid chlorine, and an overhead travelling crane facilitates the handling of these liquid chlorine containers.

Park Features. The filtration works and low-level pumping station are located on an 80-acre tract of ground between the water-supply aqueduct and the city of Verdun. An attractive iron fence, 5 000 ft. in length, marks the boundary line on three sides of the property. There are eight gate entrances to afford easy access to all parts of the works. The north end of the property has already been made into an attractive park by the construction of driveways and paths, grading and seeding and the planting of trees and shrubs. Two lagoons, each 50 ft. by 150 ft., with water sprays

and several flower beds greatly improve the appearance of the new low-level pumping station.

This year we are grading, seeding and planting about eight more acres; and at this rate of progress it will only require a few years to develop the whole property. Largely due to the interest shown by the filtration staff during the last few years, in the growing of plants and flowers, a small greenhouse 18 ft. by 37 ft., is now under contract. It is so located that access is available from a covered passage from Filter Gallery No. 1 and will permit the growing of plants for the outside flower beds and for decorating the filter buildings and pumping station.

Operation.

Raw Water Supply. The two river intakes from which the filtration works obtains its supply of raw water are located about 20 miles below the confluence of the St. Lawrence and Ottawa rivers. The intake normally in use is about 1 200 ft. from shore; the other or shore intake is protected by ice cover in winter and can be used when frazil ice causes trouble in obtaining the required volume from the outer intake. Both intakes supply varying mixtures of the St. Lawrence and Ottawa rivers water, depending upon seasonal and local weather conditions. The shore water is largely Ottawa River water and carries all the domestic pollution of 12 small towns, except that which is diverted into the Lachine Canal.

From these intakes, the raw water is conveyed by the Montreal Aqueduct Canal and its lateral conduit, a distance of about five miles to the filtration works. The lower 3 miles of the Montreal Aqueduct Canal now serve as a sedimentation basin with about 30 hours' storage at a 100-m.g.d. rate of flow which quite materially reduces the number of bacteria of sewage origin in the raw water before it reaches the filtration works.

As regards physical characteristics, the outside water is more desirable than that from the shore. Turbidity is not a serious problem, as neither river carries much suspended matter except for short periods in the spring and sometimes in the fall. The normal color of the St. Lawrence River (outside water) is from 10 to 15 p.p.m., while the color in the shore water may reach a maximum of 80 p.p.m. The operator therefore endeavors to have the intakes controlled in such manner as to reduce as far as possible the entrance of shore water.

Bacterial Removal. In 1927, the rapid sand filters showed an average bacterial removal of 73 per cent., when operated at an average rate of 139 m.g.d. per acre without use of coagulant. The final filters, with a mixture of raw and pre-filtered water in the approximate ratio of 3 to 4 as applied water, showed an average bacterial removal of 85 per cent., when operated at an average rate of 11.5 m.g.d. per acre. The overall bacterial removal by filtration (*i.e.* before chlorination) was 87.5 per cent.

Chlorination. The slow sand filter-effluent and that part of the rapid

sand filter-effluent diverted to the filtered-water basin to make up the total daily demand on the plant have been chlorinated during the past year at their mixing point in Gatehouse No. 2. A small sample pump returns chlorinated water from a point in the filtered-water basin representing an absorption period of about two minutes. Hourly samples at this point show the residual chlorine content under these conditions to be very uniform.

Occasionally 16 tests are made in rapid succession. These tests are always within .03 to .05 p.p.m. variation from the standard required and show that the mixture of chlorine is instantaneous and uniform, a condition essential to obtain high efficiency. The dose is varied to obtain 0.2 to 0.3 p.p.m. residual chlorine after two minutes' absorption.

The percentage of Ottawa River water at the intake varies seasonally and may vary daily through the agency of high winds. The dose is increased or decreased as the percentage of Ottawa River water is greater or less. "Straight" Ottawa River water requires seven times as much chlorine as that from the St. Lawrence to insure practical sterility. The overall removal of bacteria after chlorination for the past year was 99.9 per cent.

GENERAL CHARACTERISTICS OF WATER FROM PLANT, 1927.

	Max.	Min.	Ave.
Alkalinity ($CaCo_3$) (p.p.m.)	82	60	71
Turbidity (p.p.m.) *Less than*	2	2	2
Color (p.p.m.)	30	7	22
Incrusting solids (p.p.m.)	12.6	9.3	11.0
Total solids (p.p.m.)	129	109	118
Bacteria per cc	12	3	6
B. Coli per 10 cc. *Less than*	1	1	1

Operation Records. The following tables show the details of operation during the year 1927:

TABLE 1.
Combined Final Filter Record — 1927.

No. of Filter.	Total No. of Washes.	Average Loss of Head.			Average Length of Wash.		Average Period of Service.		Average Rate Before Wash (m.g.d.).	Total Wash Water Used (m.g.).
		Initial.	Final.	Regain.	Hours.	Min.	Days.	Hours.		
1	24	4.05	7.96	3.91	9	50	15	04	4.01	2.215
2	24	3.88	7.67	3.79	9	42	14	10	3.96	2.111
3	21	3.82	7.65	3.83	9	39	16	06	3.94	1.799
4	19	4.05	7.70	3.65	9	38	17	01	3.80	1.626
5	25	4.28	7.38	3.10	9	21	14	05	3.76	2.088
6	24	4.02	7.46	3.44	9	18	15	01	3.60	2.076
7	23	4.02	7.50	3.48	9	55	13	19	3.90	1.972
8	23	4.46	7.61	3.15	9	49	15	09	3.65	1.972
9	21	4.01	4.43	3.42	9	45	15	07	3.88	1.799
10	27	4.10	7.27	3.17	9	50	13	12	3.79	2.353
11	24	4.38	7.49	3.11	9	48	15	00	3.84	2.110
12	26	4.41	7.55	3.14	9	50	14	06	3.91	2.284
13	26	4.93	7.85	2.92	9	50	13	12	3.91	2.249
14	28	4.51	7.40	2.89	9	30	12	09	3.77	2.387
15	19	4.54	7.73	3.29	10	07	19	03	3.85	1.731
16	21	4.71	8.05	3.34	9	41	16	17	4.06	1.799
Total	375	....	....	....	....	....	....	....	....	32.571
Average.....	23	4.26	7.61	3.35	9	43	15	02	3.85	2.036

TABLE 2.
AVERAGE RUNS — Final Filters — 1927.

Month.	No. of Washes.	Average Runs.	
		Days.	Hours.
January	22	22	8
February	15	29	12
March	30	16	4
April	42	11	4
May	46	10	9
June	41	11	12
July	36	13	12
August	38	12	18
September	23	20	15
October	24	20	8
November	23	20	13
December	36	13	7
Total	376	..	..
Average	31	16	22

TABLE 3.
MAXIMUM AND MINIMUM YIELDS — FINAL FILTERS — 1927.

Month.	Maximum m.g.d.	Minimum m.g.d.	Average m.g.d.
January	82.32	62.47	70.87
February	87.45	75.75	81.70
March	84.39	76.94	80.82
April	81.20	23.19	66.48
May	61.74	22.50	40.73
June	71.06	58.72	65.25
July	71.77	56.87	65.09
August	74.74	63.71	71.41
September	76.17	67.59	72.96
October	74.91	62.03	69.36
November	78.59	62.41	66.58
December	77.66	64.41	70.90
Average	76.83	58.05	68.51
Filter	4.80	3.63	4.28
Rate, m.g.d. per acre	12.81	9.68	11.42

TABLE 4.

AVERAGE RUNS — PRE-FILTERS — 1927.

Month.	No. of Washes.	Average Runs. Hours.
January	83	143
February	77	139
March	149	80
April	847	13
May	421	28
June	239	32
July	283	42
August	197	60
September	89	129
October	90	132
November	134	86
December	149	80
Total	2 758	964
Average	230	80

TABLE 5.

MAXIMUM AND MINIMUM YIELDS — PRE-FILTERS — 1927.

Month.	Maximum m.g.d.	Minimum m.g.d.	Average m.g.d.
January	56.00	55.78	55.85
February	56.00	55.69	55.84
March	56.00	55.24	55.79
April	55.64	51.19	55.23
May	55.78	51.03	55.43
June	55.80	54.10	55.58
July	56.00	51.28	55.47
August	55.83	54.80	55.64
September	56.00	54.17	55.76
October	55.85	54.31	55.75
November	55.85	55.69	55.81
December	56.00	53.08	55.70
Average	55.90	53.86	55.65
Filter	3.49	3.37	3.48
Rate, m.g.d. per acre	139.75	134.65	139.13

TABLE 6.

STERILIZATION PLANT RECORD — 1927.

Daily Averages.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
Water Treated (m.g.d.)													
Pre-filter	7.45	2.85	0 .73	14.77	44.09	20.84	24.03	18.77	17.37	17.81	16.85	15.78	16.78
Final Filter	70.87	81.64	80.82	66.49	40.51	65.25	65.09	71.41	72.96	69.36	66.58	70.90	68.49
Total	78.32	84.49	81.55	81.26	84.60	86.09	89.12	90.18	90.33	87.17	83.43	86.68	85.27
Liq. Chlorine (Lb.)													
Raw	...	159	90	305	...	...	...	...	...	...	...	...	46
Filtered	437	465	465	349	415	471	433	442	331	262	329	403	400
Total	437	624	555	654	415	471	453	442	331	262	329	403	446
Dose (p.p.m.)													
Raw	...	.38	.37	.38	...	...	...	...	...	...	...	...	.38
Filtered	.56	.55	.57	.43	.49	.55	.49	.49	.37	.30	.39	.47	.47
Bacteria per cc. Treated Water	7	6	10	7	2	5	3	4	5	4	7	12	6
Fermentation Test 48 hours. 10 cc.	1/275 0.4	3/260 1.2	0/290 0.0	0/265 0.0	1/283 0.4	1/265 0.4	1/255 0.4	15/550 2.7	0/275 0.0	0/285 0.0	7/280 2.5	2/420 0.5	31/3 713 0.8

TABLE 7.

Monthly Analysis of Influent and Effluent — 1927.

Month.	Total Output m.g.d.	Alkalinity.	Color.	Turbidity.				Bacteria. Agar 96 Hrs. 20° C.					Fermentation Tests. Lact. Pept. Bile, 72 Hrs. 37° C.						
													Raw Water.		Pre-filt. Eff.		Final Filt. Eff.	Treated Water.	Treated Water 48 Hrs.
				Raw Water.	Pre-filt. Eff.	Fin. Filt. Inf.	Fin. Filt. Eff.	Raw Water.	Pre-filt. Eff.	Fin. Filt. Inf.	Fin. Filt. Eff.	Treated Water.	1.0 cc.	10.0 cc.	1.0 cc.	10.0 cc.	10.0 cc.	10.0 cc.	10 cc.
Jan.	78.3	67	25	6	..	..	2	10 000	...	2 850	490	7	78/160	159/160	...	...	92/150	8/265	1/275
Feb.	84.5	60	30	5	..	..	2	10 900	...	4 200	750	6	52/140	110/140	...	...	59/140	24/380	3/260
Mar.	81.5	67	26	6	2	4	2	11 600	4 200	6 600	2 200	10	50/175	161/175	28/145	130/155	83/155	5/295	0/290
Apr.	81.3	71	25	8	2	..	2	...	Results for Month of April are given below:										
May	84.8	71	22	7	2	6	2	4 500	375	3 600	120	3	24/165	120/160	...	92/295	7/155	4/283	1/283
June	86.1	67	24	7	2	4	2	2 500	150	1 400	37	5	27/150	126/150	...	83/340	2/145	1/265	1/265
Jul.	89.1	69	20	4	2	5	2	2 100	180	1 000	28	3	23/155	117/155	7/145	114/445	4/155	2/255	1/255
Aug.	90.2	72	18	8	2	5	2	1 600	325	960	37	4	22/145	141/155	5/140	108/210	6/155	28/560	15/560
Sept.	90.3	79	10	7	2	4	2	1 400	300	850	23	5	25/150	142/150	4/135	79/150	15/148	2/275	0/275
Oct.	87.2	82	7	6	2	4	2	2 600	950	1 800	34	4	45/155	145/155	15/155	102/155	13/160	0/285	0/285
Nov.	83.4	74	29	13	3	8	2	8 700	3 700	6 000	750	7	82/150	143/145	49/150	126/150	66/150	22/280	7/280
Dec.	86.7	73	29	15	2	8	2	19 000	6 400	11 500	1 900	12	21/150	99/155	55/155	154/155	126/155	8/420	2/420
Total	...	..	..	..	..	..	..	...	...	...	...	..	449/1 695	1 493/1 700	163/1 025	988/2 055	473/1 668	104/3 563	31/3 713
Aver.	85.3	71	22	8	2	5	2	6 800	1 850	3 700	600	6	26.5%	87.8%	15.9%	48.1%	28.4%	2.9%	0.8%
April Results: Raw Water before Chlorination ...								7 300	...	...	...	..	8/215	108/205	...	...	...	...	...
Raw Water after Chlorination								20	4	0	3	7	...	62/195	...	24/200	6/145	11/265	0/265

TABLE 8.

COST OF OPERATION.

Distribution.	Operation.		Maintenance and Repairs.		Total.	Cost per m.g. (Imp.)	Per Cent.
	Wages.	Supplies.	Wages.	Supplies.			
Supervision	3 213.00	....	567.00	....	3 700.00	.12	5.86
Pumping Station	10 866.60	313.57	361.41	297.03	11 838.61	.38	18.36
Pre-filters	4 575.39	272.06	698.77	63.47	5 609.69	.18	8.70
Final Filters	3 474.35	366.50	1 238.76	1 540.26	6 619.87	.21	10.27
Laboratory	3 085.68	1 489.90	255.98	41.50	4 873.00	.16	7.56
Sterilization	2 417.12	12 534.75	462.45	245.03	15 659.35	.50	24.29
Electric Current	....	14 240.00	....	....	14 240.00	.46	22.08
Building and Grounds	....	....	1 737.91	120.58	1 858.49	.06	2.88
Total	27 632.14	29 216.78	5 322.22	2 307.87	64 479.01	2.07	100.00

Total Filtrate in 1927— 31 125.12 m.g.

TABLE 9.

IMPROVEMENTS DURING TEN YEARS' OPERATION.

	1918.	1919.	1920.	1921.	1922.	1923.	1924.	1925.	1926.	1927.
Unfiltered but chlorinated raw water added to filtered effluent to make up total city demand. m.g.d.	20.3	13.5	21.8	19.5	19.8	10.6	13.4	7.7 *	0.8	0.0
Raw water added to final filter influent to allow of increased output from final filters. m.g.d.	0.0	0.0	0.0	0.0	0.0	4.8	3.2	11.3	19.6	29.6
Total filtered m.g.d.	42.7	50.8	51.2	50.0	56.2	59.8	58.2	66.3	75.6	85.3
Total consumption m.g.d.	63.0	64.3	73.0	69.5	65.0	70.4	71.6	73.8	76.4	85.3
Total cost purification including chlorination.										
m.g.d. (Imp.)	....	....	4.70	4.71	4.62	3.52	3.78	3.23	2.96	2.07
m.g.d. (U. S.)	....	....	3.76	3.77	3.70	2.82	3.00	2.58	2.37	1.66

RECENT DEVELOPMENTS IN WATER PURIFICATION.

BY WELLINGTON DONALDSON.*

[*Read September 19, 1928.*]

In determining the significance of changes or innovations in water-works practice, there is much latitude for individual judgment. Changes may represent merely fugitive experiments on the one hand, or on the other hand may be destined to find a permanent place in development of the art of water purification. The water-works field is a wide one: local conditions are quite diverse; modifications of processes considered highly advantageous in one locality are wholly inapplicable in another where the character of water or other local condition is different. In this paper the author will attempt to indicate briefly his personal reaction towards those recent changes in established practice that seem to him to possess the greatest general interest.

Speaking generally, the most notable recent advances have been concerned with processes or modifications of processes rather than with new types of structures. Of the structural changes noted in a survey of the more recent purification plants, the most important are concerned with mechanically-cleaned settling basins, mixing facilities and aëration.

Mechanical Clarifiers. Originally developed as a metallurgical process, the mechanical clarifier has been finding increased favor in water-works practice. Its first point of entry into water-works practice was in connection with softening plants where the voluminous precipitate produced by lime and soda reactions indicated advantages through continuous removal of sludge, in contrast with the usual practice of intermittently emptying and flushing the settling units. The mechanical clarifier, at first circular in plan with crescentic inlet and outlet troughs, has developed into a square plan having more efficient settling characteristics. The early installations were separate, independent structures. The tendency now is to incorporate the clarifier in one end of a rectangular settling basin, the two structures being integral and with a continuous water surface.

The first mechanical clarifier installation of record in connection with municipal water works was at Benton Harbor, Mich.; put in service in 1923. At the present time the mechanical clarifier has been incorporated in the design of some 14 water-softening plants, chief among which are Newark, Ohio; Piqua, Ohio; Springfield, Ill.; Miami, Fla.; and South Pittsburgh, Pa. The efficiency and economy of these devices, in comparison with the older style settling basins, are not yet fully established, but their popularity would indicate that mechanically-cleaned basins of some type are likely to find a permanent place in connection with water softening.

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The utility of the mechanical clarifier for removal of the sludge from softening reactions has more recently been extended into other water-purification fields. At Lancaster, Pa., and Decatur, Ill., clarifiers are used to serve in place of ordinary coagulating basins. The latest adaptation is a preliminary sedimentation device for the very turbid waters of the middle West. The Missouri River, for instance, has an established peak of 15 000 p.p.m., or 62 tons of dry suspended solids per million gal., while values of 5 000 to 8 000 p.p.m. are not uncommon occurrences during the spring and summer months. The customary practice on the Missouri and other muddy western rivers has been to provide extensive preliminary sedimentation in simple rectangular basins. The large amount of sediment deposited in these basins has necessitated putting them out of service frequently for cleaning purposes, with considerable inconvenience to operation and cost for labor and flushing water. These facts have led to the idea of continuous removal of the deposited sediment in a more satisfactory manner than can be obtained by well-sloped or underdrained bottoms. The result has been an incorporation of mechanical clarifiers in at least two of the important Mid-west plants. The Kansas City, Mo., plant, which went into operation in June of this year, has four 200-ft. diameter, circular clarifiers as preliminary sedimentation units. The new Missouri River plant of the St. Louis water works, now under construction, includes five 150-ft., square clarifiers for preliminary sedimentation ahead of the softening processes. Operating results are not yet available at Kansas City under normal conditions to give a comparison with plain rectangular basins as to efficiency of removing suspended solids and operating costs. Until these points are settled, it is fair to regard the matter as in an experimental state, in so far as these two installations may have a bearing on influencing practice in handling excessively turbid waters. They at least constitute a notable modification over the customary plant layout.

Mixing Facilities. Another feature of filter plant layouts that has been undergoing extensive modification within recent years, is the mixing arrangement for facilitating the chemical reactions connected with softening or coagulation. The lack of flexibility of the older, baffled type of mixing chamber for varied conditions of flow are well recognized and have led in recent years to experimentation with other types of mixing devices, though as yet no standard design has been evolved. The Topeka softening plant has a loosely-baffled chamber with mechanical stirrers. Many of the recent softening plants employ single circular mixing chambers with mechanical stirrers. The Sacramento, San Leandro and Beverly Hills plants employ multiple circular mixers with paddle stirrers, operated in tandem. Knoxville, Tenn., is another recent example. The plants at Providence, R. I., Watertown, N. Y., Albany, N. Y., and Danville, Va., have circular mixing tanks without mechanical stirring devices, the tangential bottom inlets and tangential top outlets being relied upon to produce stirring velocities. The Kansas City and St. Louis works have

somewhat similar mixing devices, with the difference that the tangential inlet is at the top while the outlet is at the center of the cone-shaped bottom. The flow is thus downward in a vortex.

Still another notable type is the "hydraulic jump" installed in the new 165-m.g.d. Fairmount filter plant at Cleveland. The same feature is incorporated in plants at Bay City, Mich., Port Arthur, Tex., Hannibal, Mo., Lake Charles, La., and Hamlet, N. C. Most of these newer types of mixing devices appear to be working satisfactorily, with advantages over the older types.

Aëration. Prior to the general adoption of filtration, aëration was regarded as an effective weapon for combating odors and tastes in stored waters. Later the marked benefits derived from filtration somewhat obscured the advantages of aëration, and many representative filter plants, built a few years ago, were provided with meager or no facilities for aëration. More recently, however, there has been a recrudescence of the aëration idea as water consumers have become more critical of the physical qualities of the supply. In several instances aëration of both raw and filtered water is practiced.

Aëration is now employed for other than the original purpose of overcoming tastes and odors due to plankton growths or the effects of stagnation in stored water. Certain classes of trade waste responsible for taste and odor respond favorably to aëration, though others do not. At West Palm Beach and a few other places, addition of the alum dose prior to passage of the raw water through spray nozzles has been found distinctly helpful in promoting coagulation of a soft colored water. At both Richmond, Va., and Rahway, N. J., it has been found that spray-nozzle aëration is quite effective after substantial pre-chlorination doses in reducing residual chlorine to within non-troublesome limits. Another use for aëration that has come to the front, is its ability to lower the carbon dioxide content, thereby decreasing aggressiveness of the water. This has led to the use of the so-called effluent aërators as exemplified by the plants at Albany, Providence, West Palm Beach and Poughkeepsie.

That the aëration feature, aside from its utility, can be made to serve an ornamental purpose is shown very well by the Kensico and Ashokan installations of the New York water supply, and those at Providence, West Palm Beach and the San Leandro plant of Oakland.

In general, where the need of aëration is plainly indicated, the tendency has been towards the use of fixed spray nozzles in preference to other devices that are not so completely effective. Mention deserves to be made, however, of the floating nozzles in the Sacramento and Beverly Hills installations. In the latter, the released hydrogen sulfide gas is captured and discharged through a tall stack to avoid complaints in a high-class residence district.

Filters. No important changes in filter design have come to the front recently. There still exists considerable diversity of opinion as to the merits

of various styles of underdrain systems; none of them are perfect and most of them are satisfactory. Of the filter appurtenances such as gages, controllers, etc., new designs have appeared within the last year or so, but nothing particularly novel has developed, excepting the substitution of electrical instruments at Wausau, Wis., for the usual filter flow-gage. It seems to be merely a question of healthy competition among the manufacturers.

It is worth noting here the revival of the old Hyatt idea of washing a filter bed by sections instead of as a whole. It will be remembered that some of the early New York Continental filters employed the "quadrant" wash for a single undivided bed, but the idea fell into disuse. It has been revived in a modified form in some of the recent plants for washing beds made up of separate bays; for instance, at Poughkeepsie and West Palm Beach where the four bed sections are washed independently, and at the San Leandro, Calif., plant where the filter is washed by halves. The purpose obviously is to reduce the size of wash piping required and the demand rate of wash water.

Coagulants. Much experimentation is continually being carried on in various parts of the country to discover coagulants better suited than is ordinary filter alum to certain types of water and to decrease the cost of the preparatory treatment. These experiments have dealt mostly with some form of sodium aluminate under various trade names, usually supplementary to alum. Results reported in some places are distinctly favorable, but in others the trials have shown no advantage either as to efficiency or cost over the customary treatment.

The repertory of water treatment chemicals is continually increasing. From Elizabeth City, N. C., comes a report of the successful use of chlorinated copperas as a coagulant for a soft, highly colored (550 p.p.m.) swamp water after comparison with alum and sodium aluminate as a primary coagulant. The treatment is carried out by simply feeding chlorine to the copperas solution delivered by a dry-feed machine.

Chlorination. The chlorination of water has expanded considerably. In addition to the common practice of applying the chlorine in a single dose to the plant effluent, many plants are now making use of split treatment, or application at two points. The practice is not uncommon of treating both raw and filtered water where heavy bacterial loading exists. In this case, application to the raw water is usually referred to as "prechlorination." Hackensack, N. J., is a recent convert to this practice, about 0.5 p.p.m. being used as a primary dose to the inlet of the coagulating basins and a second dose of 0.15 p.p.m. being given to the filter-effluent. At Toledo, Ohio, the filtered water is treated twice to secure satisfactory bacterial results. At Richmond, Va., split or double chlorination is practiced in order to keep down algal growths in a shallow, exposed clear-water basin of considerable area. At Kansas City, Kan., a second application of chlorine is used to control algal growths in a distributing reservoir.

Another important use for chlorine is the so-called super-chlorination process whereby an unusually large dose is applied for the purpose either of overcoming extraordinary pollution or of destroying obnoxious substances, such as phenols, which the water supply may contain. This method involves a secondary application of sulfur dioxide or other anti-chlor for reducing the excess chlorine that would otherwise cause taste. It should be pointed out that super-chlorination is directed primarily to the destruction of taste- and odor-producing substances that are not removed by the familiar processes of coagulation and filtration. In somewhat the same category, but widely different in principle, are the Cleveland experiments for removing taste and odor by filtration through a special activated carbon. So far as the writer is aware super-chlorination first exploited in America by Howard at Toronto is now used on a routine basis only at Rahway, N. J.

Softening. The last few years have witnessed notable additions to the list of softened municipal supplies in this country. Advances in this art have been due, as C. P. Hoover has pointed out, to the recarbonation feature which not only obviates incrustation, but results also in effective sterilization and enables more complete softening to be carried out than hitherto possible by the lime-soda process, and at less cost. Simpler and more dependable methods of recarbonation have been developed. The pneumatic system of handling lime, as used at Springfield, Ill., gives promise of modifying the older mechanical-conveyor method.

As regards zeolite softening, there are now seven installations in service for municipal water supplies in this country. With the exception of the 4.0-m.g.d. plant of the Ohio Valley Water Co. at McKees Rocks, the installations are all quite small, ranging from 40 000 to 200 000 gal. per day capacity. However, the extreme hardness of the water handled by some of them is notable.

The 2.0-m.g.d. plant at Sewickly, Pa., now nearing completion, is notable for being constructed along lines of ordinary rapid sand filters. In other words, reinforced concrete replaces the steel-shell construction found in the other municipal installations.

Modified methods of washing and regenerating the zeolite filter have come to the front, but in these it is not easy to distinguish between merit and salesmanship. From the published results, however, it appears that the McKees Rocks plant has succeeded in reducing materially the all-important salt ratio. It is interesting to note that a few industrial zeolite installations are reported to be using sea water or oil-well brine for regeneration.

Conclusion. As stated at the outset of this paper, the matters that have occupied the attention of water-works people lately are not so much new design features as the modified use of purification facilities already available along the lines of coagulation, softening and chlorination. The indications are that treatment of water, instead of being simplified, is

becoming more complex and more highly specialized. The standards for hygienic safety have for some years been fairly well met. Now there is beginning to come to the front, more prominently than ever before, the expectation that public water supplies will not only be free from danger to health, but also agreeable in physical properties and reasonably low in hardness or other chemical constituents that affect their use not only by domestic consumers but by industries as well. How else can we interpret the refinements now taken for maximum color reduction, for taste and odor control, and the growing demand for softer water!

THE NEW WATER-WORKS SYSTEM OF THE GREENWICH WATER COMPANY.

BY DANA M. WOOD.*

[*Read September 19, 1928.*]

This paper describes briefly the historical development of the Greenwich Water Company, and its existing plant prior to recent improvements. It further outlines the study of the several possible sources of additional supplies and needs of the company, and concludes with a discussion of some of the more interesting features of the recent additions to and improvements in the supply.†

Greenwich Water Company including Port Chester Water Works. The Greenwich Water Company was organized under the laws of Connecticut under a special charter dated March 24, 1880, subsequently amended several times. The first stockholders' meeting was held April 17, 1880, and officers elected. On April 30, 1880, a contract was awarded to Richard W. Sherman of Utica, N. Y., for the erection and completion of a dam (Putnam Lake) and pipe distribution-system in Greenwich. The first tap was made in June, 1880.

On April 14, 1883, action was taken to extend the lines to East Port Chester, Port Chester and town of Rye, the latter two communities being in the State of New York, and the Board of Directors was increased from five to seven members. Because of the interstate situation, the subsidiary company, Port Chester Water Works, was formed, all of the profits from which were transferred to the Greenwich Water Company in payment for water.

A pipe line was laid from the Mianus River, and finally from a diversion dam on Pipen Brook, between 1905 and 1909 to obtain an additional water supply. Rockwood Lake was created in 1907–1908. Putnam Lake dam was rebuilt during 1909–1912. The Byram River tunnel was built during 1913–1914 to divert additional water from the Byram River.

In September, 1925, Stone & Webster, Inc. were asked to examine the properties with a view to purchase by Putnam & Storer, Inc. of Boston, and after acquisition to continue their investigations to ascertain (1) the immediate construction requirements for serving the existing territory with reasonable provisions for the future, and (2) the possibilities for serving a greatly increased territory perhaps extending from Stamford to New York City. This necessitated the location and examination of undeveloped sources of water supply, a consideration of purification requirements and possible feeder-line routes.

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†Description of the design and operating features of the purification plant is the subject of the succeeding paper by E. Sherman Chase.

The new owners also organized the Greenwich Gas Company and employed Stone & Webster, Inc. to design and construct a gas distributing-system in Greenwich, where previously there had been practically no such service. The entire capital stock of this company, together with that of the Greenwich Water Company is held by the newly organized Greenwich Water and Gas Company.

S. E. Minor & Co. of Greenwich were retained to assist in making necessary preliminary field surveys of reservoir sites and pipe-line routes for the water company. Metcalf & Eddy, Engineers, of Boston, were later retained by Stone & Webster, Inc. as engineers on the purification plants. They in turn employed Frank A. and Frederic M. Kendall of Boston as architects on the Putnam Lake purification plant, to be described later.

Early in 1928 the Greenwich Water and Gas Company was acquired by the Community Water Service Company controlled by P. W. Chapman & Company.

Existing Physical Plant.

The water supply for the Greenwich Water Company, including its subsidiary, the Port Chester Water Works, is obtained from two connected artificial reservoirs, Putnam and Rockwood lakes. Water is diverted from the Mianus River, an adjacent watershed to the east, into Rockwood Lake, and from the Byram River, an adjacent watershed to the west, into Putnam Lake.

Rockwood Lake. Rockwood Lake is located on West Brother Brook, the westerly branch of Greenwich Creek, and has a natural watershed area of 0.75 sq. mile. Its area at flow-line elevation of 327 ft. is 110.4 acres, and its capacity for full draft of 29 ft. is 500 million gal.

The reservoir is created by an earth dam with concrete core wall, the upstream face being riprapped, 37 ft. high and 450 ft. long. It is connected with Putnam Lake by about 1 500 ft. of 20-in. cast-iron pipe having an outlet gate on the shore of the latter. A 16-in. emergency pipe-line passes around Putnam Lake to the old filter plant.

Putnam Lake. Putnam Lake is located on Horse Neck Brook, tributary to Long Island Sound, and has a natural watershed area of 2.05 sq. miles. Its area at flow-line elevation of 300 ft. is 104.9 acres, and its capacity for full draft of about 29 ft. is 572 million gal.

The reservoir is created by an earth dam with concrete core wall, the upstream face being riprapped, 35.5 ft. high and about 640 ft. long. A 50-ft. spillway is located at its westerly end. An outlet-gate structure of concrete conducts the water to a 30-in. cast-iron pipe which is the main feeder to the distribution system, and to a 24-in. blow-off line now also interconnected to the 30-in. feeder below the dam.

Brush Dam. Brush Dam is located on Pipen Brook, a tributary of Mianus River, at a point where the watershed area is 1.65 sq. miles. It creates a reservoir having an area at its flow-line elevation of 362 ft. of

about 4 acres, and a capacity of about 14 million gal. The dam is of concrete, of non-overflow type, about 25 ft. maximum height and 243 ft. long, with a 30-ft. spillway at its easterly end.

This reservoir is connected with Rockwood Lake by about 2 miles of 20-in. cast-iron pipe.

Emergency Pumping-Plant, Mianus River. During the fall of 1926 an emergency pumping-plant was installed on the Mianus River at the so-called Todd property, consisting of two 700-g.p.m., 1-m.g.d., 75-h.p. gasolene-engine-driven centrifugal pumps located in a standard 20 x 30 ft. metal building. The pumping head is about 185 ft. The total watershed area at this point, including that above Brush Dam, is 18.65 sq. miles. This plant pumps directly into the 20-in. pipe line from Brush Dam to Rockwood Lake.

Byram River Diversion. At a point on the east branch of the Byram River opposite Round Hill where the drainage area is about 4 sq. miles, a low concrete weir with wood stop-logs facilitates the diversion of the run-of-river to a 6½-ft. diameter tunnel leading to the upper end of Putnam Lake. This tunnel in rock is about 4 200 ft. long and unlined.

Converse Lake. Converse Lake, in the headwaters of the east branch of the Byram River, is privately owned but has been used on several occasions of extreme drought by private arrangement. Its area at flow-line elevation of about 422 ft. is about 105 acres, and its capacity is about 325 million gal. for a maximum draft of 20 ft. With an 8-ft. draft, the area is reduced to about 75 acres, the capacity being about 235 million gal. The watershed area is about 1.02 sq. miles.

Old Filter Plant. Formerly the water was conducted from the Putnam Lake outlet through a 30-in. cast-iron pipe line to a chlorinator, through a 30-in. Venturi meter and alum-treatment house; and thence to two single-story buildings containing pressure filters.

The duplicate chlorinators are automatic-control, direct-feed machines, type ADMV, made by Wallace & Tiernan, and are located about 1 500 ft. below Putnam Lake. One filter building, partly of rubble stone and partly of wood, approximately 67 x 40 ft., houses two horizontal filters of 0.5 m.g.d. capacity each, made by the New York Filter Co., and 6 vertical Federal filters of 0.25 m.g.d. capacity each. The other building of rubble stone, approximately 38 x 42 ft., houses 6 vertical filters of 0.25 m.g.d. each, made by the New York Continental Jewel Filtration Company. The combined normal rated capacity is, therefore, 4 m.g.d. Thence the water is conducted through several feeders to the distribution system.

Standpipes. There are two standpipes on the system. One is located on Lake Avenue in the town of Greenwich and about 2 miles below the filtration plant above described. It is 80 ft. in diameter, 35 ft. high and holds 1 333 000 gal. Its top elevation is 275 ft.

The other is located on Summit Avenue in the village of Port Chester. It is 60 ft. in diameter, 50 ft. high and holds 1 057 000 gal. Its top elevation is 210 ft.

Both standpipes are of steel construction and are equipped with Golden-Anderson altitude-control valves.

Distribution System. General maps of the distribution system have been prepared by Stone & Webster, Inc. to assist in studying the routes for feeder lines, but in other respects the distribution system has not been studied and is not further mentioned in these notes.

Investigations of Additional Supplies.

Preliminary office and field investigations have been made of the several additional sources of water supply available for development by the Greenwich Water Company. In several instances the company already owns controlling parcels of land, and in other instances its charter right of condemnation by eminent domain makes the acquisition of the properties possible. Preliminary location and designs of necessary dams and purification plants have, in all cases but one, been determined. The general studies so far made serve to indicate the relative merits of the several projects and the easy determination of the next best immediate step in the construction program.

Riversville Reservoir. The Riversville project contemplates a concrete dam across the east branch of the Byram River at a point about one-quarter mile below its junction with the middle branch. The site is sometimes called the "Glenville Site" since it was acquired originally by the Glenville Power & Water Company now owned by the Greenwich Water Company. The project includes also a gatehouse with appurtenances, a purification plant having a rated capacity of from 12 to 18 m.g.d., a pumping plant of the same capacity, and a feeder main connecting with the existing Greenwich Water Company's system in a way that allows for a possible demand for more water in Westchester County, N. Y.

The total drainage area at the dam site is 11.68 sq. miles, of which 1.02 sq. miles are above the outlet of Converse Lake and 4.10 sq. miles are above the proposed outlet of the Round Hill Reservoir to be described later, leaving a net drainage area tributary to the Riversville Reservoir after complete development of the watershed of 7.58 sq. miles. The storage capacity would be about 2 690 million gal.

West Branch Diversion. In connection with the Riversville project, there would ultimately be built a diversion of the west branch of the Byram River into the Riversville Reservoir. New York City has already diverted about 7.7 sq. miles of the upper portion of the Byram River drainage into the Kensico Reservoir from near the New York-Connecticut state line, so that the diversion now contemplated would include only that portion of the watershed lying within the State of Connecticut amounting to a net drainage area of about 3.6 sq. miles. The dam would be located at a point known as the "Shultz" site. A capacity of from 269 to 409 million gal. would be available, depending upon the height of dam finally adopted.

Round Hill Reservoir. This project contemplates a concrete non-overflow dam across the east branch of the Byram River at a point opposite Round Hill where the tributary drainage area is about 4.1 sq. miles gross, or about 3.1 sq. miles exclusive of that at Converse Lake.

The dam site has been explored by borings and a general design plan prepared. The water from this reservoir would be allowed to flow down the main river channel, to be again collected at the Riversville Reservoir and there pass through an addition to the then existing purification and pumping plant at the latter.

This reservoir would have a capacity of about 765 million gal.

Emergency Diversion — Mianus River. An emergency diversion plant on the Mianus River was investigated and constructed as described under a previous heading "Existing Physical Plant."

Temporary Dam and Diversion at Todd Site. The Todd property previously mentioned is located in what may be the center of a future large reservoir to be described later under the caption "Riverhill Reservoir." Prior to constructing the latter and especially if it seems desirable to develop the water resources of the company in moderate steps, a small amount of reservoir capacity may be obtained by the construction of a temporary timber-crib rock-filled dam at the Todd site, at a point just above the present emergency pumping plant where the tributary drainage area is about 18.65 sq. miles, of which 1.65 sq. miles are above Brush Dam, the latter being described under "Existing Physical Plant." Two development schemes have been studied in detail, being identified as projects "A" and "B," differing only in the height of the dam and size of pumping plant. The former would create 18 ft. of useful storage draft equivalent to about 70 million gal. capacity. The latter would create 28 ft. of useful storage with an equivalent capacity of about 220 million gal. The respective pumping plants would be of 4 and 6 m.g.d. capacity, including stand-by unit, in both cases pumping water into the existing 20-in. feeder main leading from Brush Dam to Rockwood Reservoir. In each case an extension of the Putnam Lake purification plant would be required. The higher dam of the two appears to be the more economical.

Riverhill Reservoir. This project contemplates the construction of a concrete dam of the non-overflow type, with auxiliary spillway, on the Mianus River near Riverbank in the town of Stamford. The location of the original dam site proposed is at a point about three-fourths of a mile northeast of Stanwich, not far below the site of the emergency pumping-plant previously mentioned. An alternative site, considerably farther down the river and called the "Marshall Dam Site", would create a very much larger storage.

The drainage areas at the respective sites, inclusive of 1.65 sq. miles on Pipen Brook above Brush Dam, are 18.9 sq. miles at the upper site and 20.15 sq. miles at the lower.

The proposed dam, if located at the upper site, would create a reservoir

having a capacity of about 2 220 million gal. If the lower or Marshall site is adopted, the capacity would be about 6 330 to about 7 700 million gal., depending upon the height of dam adopted.

Palmer Reservoir. This project contemplates a storage reservoir at the so-called "Palmer Dam Site" (now undeveloped) located about $1\frac{1}{4}$ miles above the Rippowan Mills of the former Mianus Manufacturing Company and at a point where the total drainage area is about 26 sq. miles. The reservoir would have a storage capacity of about 2 000 million gal.

The main dam of the reservoir would be of the concrete non-overflow type with earth dikes at low spots beyond the main abutments and a concrete spillway section in a swale beyond the westerly abutment.

Mianus Manufacturing Company (Rippowan Mills Diversion). Several schemes for developing the property formerly owned by the Mianus Manufacturing Company, known as their "Rippowan Mills," have been considered. In the case of both the Riverhill and Palmer Reservoir sites previously described, it is contemplated to allow the water to flow down the natural channel of the river and to be collected and diverted, at the existing dam at the Rippowan Mills, to a purification and pumping plant located at this property which is now owned by the Greenwich Water & Gas Company. Each project contemplates minor changes in the vicinity of the dam with the installation of flashboards on the dam, removing the present water wheels so that a penstock to these wheels could be used as a waste way in the future, and removing a small amount of masonry at the existing waste way to permit the installation of head gates leading to a large-diameter pipe line extending to a low-lift pumping station, and thence to the purification plant.

The purification plant would include aëration and sedimentation features, filters, and filtered-water reservoirs. There would also be required a high-head pumping plant to recover system pressures.

The main feeder pipe-line would extend across the lower portion of the town of Greenwich with interconnections, and thence into Westchester County in the State of New York. The size of purification plant, pumping plant, and feeder mains would depend entirely upon size of the development made upon the Mianus River, in turn dependent upon the consumption demands and territory to be served.

Miscellaneous Considerations. Several other interrelated problems have been investigated. For example, water might be purchased from the reservoirs of the Stamford Water Company and carried through pipe lines to Rockwood Reservoir and thence through an enlarged purification plant and necessary feeder pipe-lines to the territory to be served. Owing to the wholesale price of water and its required pumping, together with the long pipe lines involved, this scheme has not been considered economical under present conditions.

It might also be possible to pump a portion of the supply from the proposed Riverhill Reservoir over the divide into Rockwood Lake and so to an enlarged purification plant at Putnam Lake.

It might be possible to connect Rockwood Lake by means of a short conduit to the existing Byram River tunnel, so that water could be diverted from the Mianus River to the Byram River, and thence to a purification plant at the site below the Riversville Reservoir.

Under the Round Hill project, it has been contemplated to permit the water to pass down the river to the Riversville Reservoir. Consideration has been given, however, to the plan of diverting a portion or all of the Round Hill storage through the Byram tunnel into Putnam Lake and thence to an enlarged purification plant at the latter point.

The foregoing will serve to indicate both the complexity of the problem in general and the number of physical opportunities available to the Greenwich Water Company for obtaining a very much enlarged water supply.

Consumption and Available Water Supply.

In developing the probable relation between consumption and available water supply, the existing Greenwich Water Company's territory was first studied, and then the assumption made that several additional communities in Westchester County, State of New York, might be added in whole or in part, one after the other. The actual sequence of increment load in any case of this sort is, of course, the result of long drawn out negotiations, with the picture constantly changing. The most that can be ascertained by a study such as has been made is the ultimate development possibility, the detail steps of which will vary according to the needs as they arise.

Therefore, in the discussion which follows, as well as in the description of projects heretofore presented, it should be kept in mind that many minor variations are possible. The first step in a comprehensive development program was taken in 1927–1928. The second will be necessary in or before 1932, but will largely depend upon conditions that cannot be foreseen at the present time. Furthermore, future relative changes in construction costs and operating revenues will affect any present conclusions as to the next best step.

Water Consumption. Satisfactory census data have in some cases been difficult to compile, due to changes in political boundaries and to floating population. Consumption data in the several municipalities are in some cases approximations and not as reliable as the engineer desires, due to the rapid growth and changes in ownership.

In making up consumption figures, therefore, we have based them on such data as could be reconciled, including actual consumption and number of services, where available. The per capita figures are higher in some communities than in others, and much can be done to improve them.

The probable average daily consumption curves for the various communities under consideration are shown in Fig. 1, predicated upon an assumed sequence of added territory and added available water supply. To the extent that consolidations are deferred or the sequence altered, this

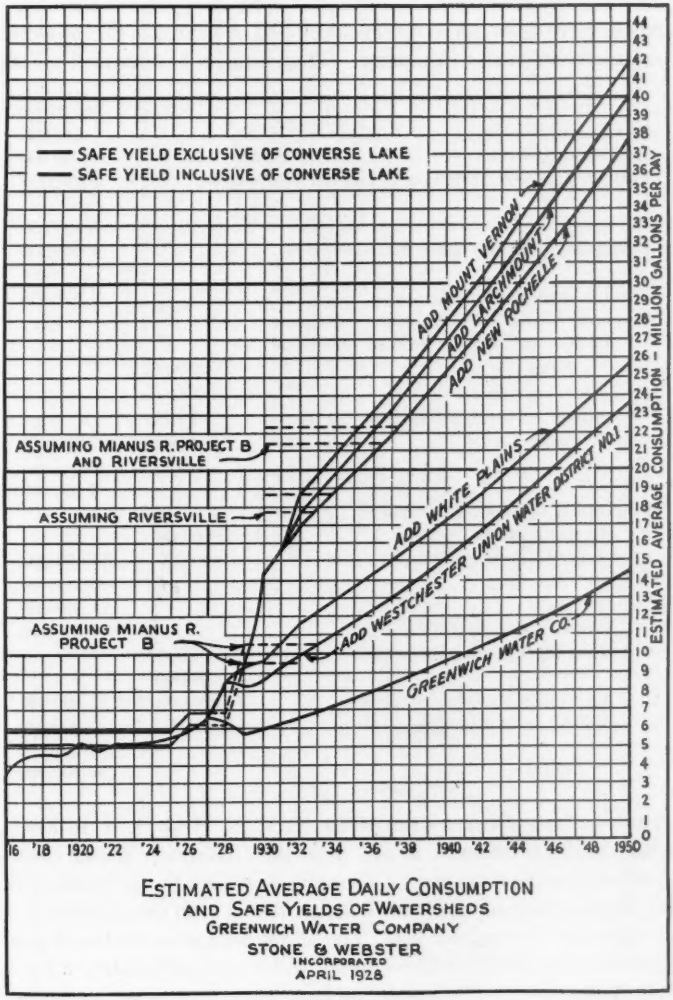

SAFE YIELD EXCLUSIVE OF CONVERSE LAKE
SAFE YIELD INCLUSIVE OF CONVERSE LAKE
ADD MOUNT VERNON
ADD LARCHMOUNT
ADD NEW ROCHELLE
ASSUMING MIANUS R. PROJECT B AND RIVERSVILLE
ASSUMING RIVERSVILLE
ASSUMING MIANUS R. PROJECT B
ADD WHITE PLAINS
ADD WESTCHESTER UNION WATER DISTRICT NO.1
GREENWICH WATER CO.
ESTIMATED AVERAGE CONSUMPTION MILLION GALLONS PER DAY
'16 '18 1920 '22 '24 '26 '28 1930 '32 '34 '36 '38 1940 '42 '44 '46 '48 1950
ESTIMATED AVERAGE DAILY CONSUMPTION
AND SAFE YIELDS OF WATERSHEDS
GREENWICH WATER COMPANY
STONE & WEBSTER
INCORPORATED
APRIL 1928

FIG. 1.

diagram must necessarily be altered from time to time. It is here presented more to show ultimate possible demand than the time at which that demand will occur.

Safe Yield of Watersheds. Estimates of the safe yield of the respective watersheds have been made, either developed or available for development by the Greenwich Water Company. They may be summarized as follows:

		Safe Yield gal. per day.
Brush Dam storage		340 000
Rockwood Reservoir		1 730 000
Putnam Reservoir, including Byram River diversion		3 030 000
		5 100 000
Emergency pumping plant, Mianus River		1 000 000
Total at present available		6 100 000
Proposed Mianus River additional diversion:		
Project A — 18-ft. storage development	2 000 000	
or		
Project B — 28-ft. storage development	3 500 000	3 500 000
		9 600 000
Proposed Riversville development:		
Riversville Dam	8 800 000	
Shultz Dam diversion	3 000 000	11 800 000
Total		21 400 000
Round Hill (net added)		1 700 000
Riverhill (upper site) — Gross	12 800 000	
Net	11 300 000	
Riverhill (lower site) — Gross	19 000 000	Net 17 500 000
Palmer (after Riverhill) — Gross	8 000 000	Net 6 500 000
Total		47 100 000

The Cos Cob power station of the N. Y., N. H. & H. R. R. has in the past been supplied about 1 m.g.d. from the Greenwich Water Company. The railroad has now developed a supply of its own by the construction of a dam and reservoir on the lower Mianus River, with an adjustment of the water rights on the entire river. The above estimates are based upon the assumption that the railroad company will require ultimately a safe yield at their development of 5 m.g.d., but to the extent that it does not require such a large supply, the amounts available to the water company will be increased.

Over 800 000 gal. per day can also be added by using an 8-ft. draft at Converse Lake, not included in the foregoing.

The above estimates have been predicated upon two years of run-off records on the Mianus River, supplemented by modifications of records

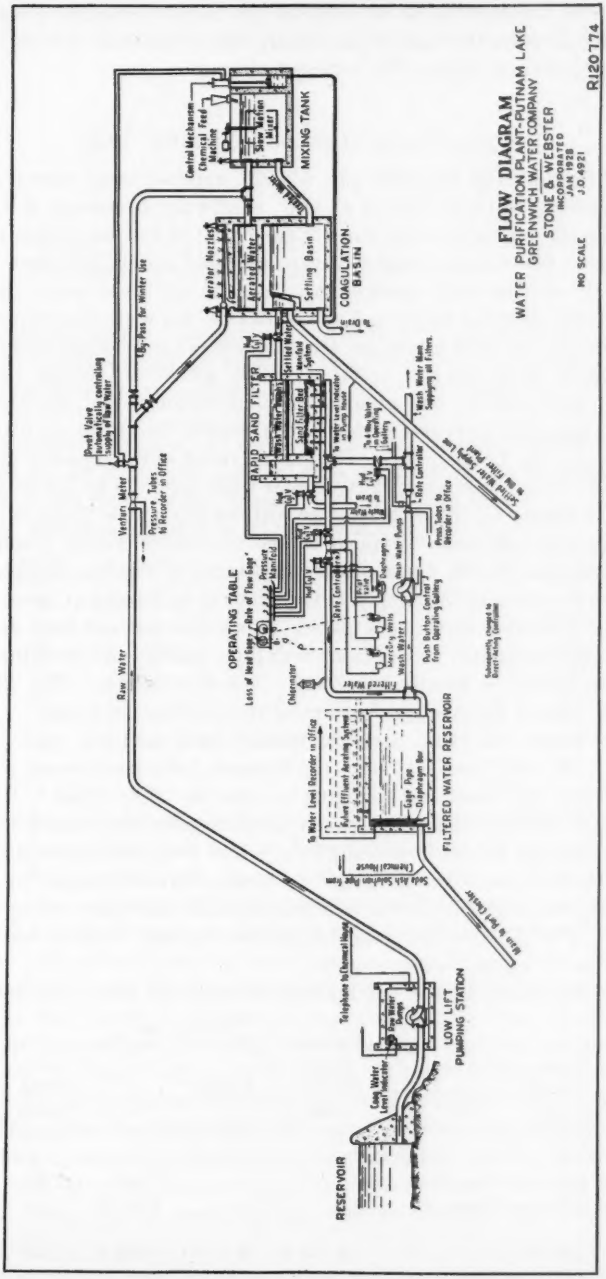

FLOW DIAGRAM
WATER PURIFICATION PLANT-PUTNAM LAKE
GREENWICH WATER COMPANY
STONE & WEBSTER
INCORPORATED
JAN 1928
NO SCALE J.O. 9921
R120774
MIXING TANK
COAGULATION BASIN
RAPID SAND FILTER
OPERATING TABLE
FILTERED WATER RESERVOIR
LOW LIFT PUMPING STATION
RESERVOIR
Raw Water
Pressure Tubes To Recorder at Office
Venturi Meter
Float Valve Automatically controlling Supply of Raw Water
By-Pass for Winter Use
Control Mechanism Chemical Feed Machine
Sand Filter Bed
Selling Basin
Aerator Nozzles
Aerated Water
To Drain
Wash Water Main Supplying Air Filters
Wash Water Tank
Wash Water Pump
Rate Controller
Press. Tubes to Recorder at Office
Chlorinator
Filtered Water
Wash Water
Hypochlorite Solution
Push Button Control from Operating Gallery
Automatically Started by Water Rising Controller
To Water Level Recorder on Office Desk
Gage Pipe
Diaphragm Box
Soda Ash Solution Pipe from (Furnace) House
Telephone to Chemical House
Low Water Level Indicator
Dry Well
Sump Pump
Main to Port Chester

FIG. 2.

elsewhere in Connecticut as a result of comparative studies. Standard safe-yield curves on the basis of one square mile of drainage area were prepared for facility in making the various estimates.

Improved Water Supply System, 1927–1928.

During 1927 and the early part of 1928, improvements were made to the Greenwich Water Company's plant, consisting in general of various changes in the piping arrangements at the outlet of Putnam Lake; the installation of two 8-m.g.d. motor-driven low-head pumps in a new pump house and receiving their water supply from the old 30-in. main; the construction of a chemical house and accessories, with a wing containing eight 0.5-m.g.d. gravity sand filters; an aëration and concrete coagulation basin consisting of three 2-m.g.d. units; a million gal. filtered-water concrete reservoir; and a 24-in., changing to 20-in. at its lower end, cement-lined cast-iron pipe line to Port Chester, and a branch line 12-in. in diameter, changing to 8-in., to Glenville. The general result of the pipe-line installation was to raise pressures in Port Chester from about 75 to 118 lb. per sq. in., and to supply Glenville, heretofore without any public water supply.

In general, all water supplied to the Greenwich Water Company's system will now receive a preliminary treatment of aëration and coagulation, then a portion of the supply will continue to be filtered at the old filter plant and a portion at the new plant. Since new and old lines are adequately interconnected, waters from both filter plants will intermingle and the entire supply be greatly improved. The flow diagram (Fig. 2) gives a general idea of the relative features of the purification plant.

Pipe Lines. A 24-in. diameter cement-lined cast-iron pipe line of Classes A, B and C was laid from the Putnam Lake purification plant to Port Chester, the lower end changing to a similar 20-in. Class C line. A 12-in. diameter cement-lined deLavaud centrifugally-cast branch line was laid to Glenville, in turn branching into 8- and 6-in. lines without cement lining. A minimum cover of three feet was adopted for the main line which in part followed highways and in part traversed private rights-of-way across country. For the most part, the line passed through territory heretofore unserved with a public water supply.

The following schedule summarizes the pipe-line work involved:

	Linear Feet.			
Main Lines.	Connecticut.	New York.	Glenville.	Total.
24″ Class A	4 045	....	....	4 045
24″ Class B	13 905.15	5 064	....	18 969.15
24″ Class C	8 096.15	....	....	8 096.15
20″ Class C	.....	4 629.5	....	4 629.5
16″ Class C	.....	80.5	....	80.5
12″ deLavaud Class 150	.....	....	2 888	2 888
8″ deLavaud Class 150	.....	....	3 521.6	3 521.6
Totals	26 046.3	9 774.0	6 409.6	42 229.9

Cross-connections, Spurs, etc.	Linear Feet. Connecticut.	New York.	Glenville.	Total.
30″	9	....	....	9
24″	.....	55	....	55
20″	196	....	....	196
16″	41	....	....	41
12″	55	....	....	55
8″	390.5	4	16	410.5
6″	274	151	37.5	462.5
4″	5	9	67	81
Totals	970.5	209	120.5	1 310.0
Combined Totals	27 016.8	9 993.0	6 530.1	43 539.9

Of the distance in Connecticut, 11 450 ft. were along private rights-of-way. Included in the total length in this State were two bridge crossings and a Venturi meter and by-pass installation at the Connecticut-New York line.

A total of 4 521 tons of cast-iron pipe and fittings, valves, etc. was installed in the pipe lines and 350 tons at the purification plant. This tonnage would require four freight trains of 50 cars each.

The estimated number of joints was as follows:

Diameter Inches.	Number of Joints.
30	3
24	2 681
20	424
16	23
12	263
8	394
6	113
4	21

On the main line in Connecticut, the equivalent of 19.5 per cent. of the length was solid rock, and in New York it was 8.5 per cent. of the length, while the Glenville branch ran 19.05 per cent. Extra earth excavation (*i.e.* necessary departures from standard trench) ran 0.0251 cu. yd. per linear ft. of trench in Connecticut, 0.077 cu. yd. in New York, and 0.002 cu. yd. on the Glenville branch.

All Class C pipe was laid with 2½-in. depth of lead in joints, and lighter pipe with 2-in. depth. A theoretical calculation of the lead required for a portion of the line gave 46 844 lb., whereas records of actual lead used gave 49 190 lb., or about a 5 per cent. excess. Untarred hemp was used for packing for lead joints and braided hemp for Lead Hydro-tite joints.

Lead joints were adopted for the main line, because there was no satisfactory water supply available for healing substitute joints. On the Glenville branch, however, which was laid subsequent to and working out from the main line, Lead Hydro-tite joints were successfully used, joints being 2½ in. deep.

All 24-in. and 20-in. pipe was laid on wooden blocks 3 x 10 x 24 in. All 45-degree bends, and where deemed necessary, other bends were anchored in concrete blocks.

On cement-lined pipe, the contractors were not allowed to use hammers and cold chisels in cutting, because of damage to the lining. A No. 3 French Patent Pipe Cutting Machine as made by A. P. Smith Company was used satisfactorily. After removal of any loosened cement, the exposed metal was coated with Barrett's Everjet Black Asphaltum. Ingersoll-Rand 2-R air hammers were used in caulking lead joints.

Because of the lack of water even for testing most of the main line, the joints were generally tested with air only. In some sections where water was available, comparative water and air tests were made to determine proper specifications for future use in the air-testing method. An interesting outcome of the use of the air for testing was the enthusiasm for it by the subcontractors, who at the start were prone to condemn it, and also the fact that better joints were obtained than by the customary water tests.

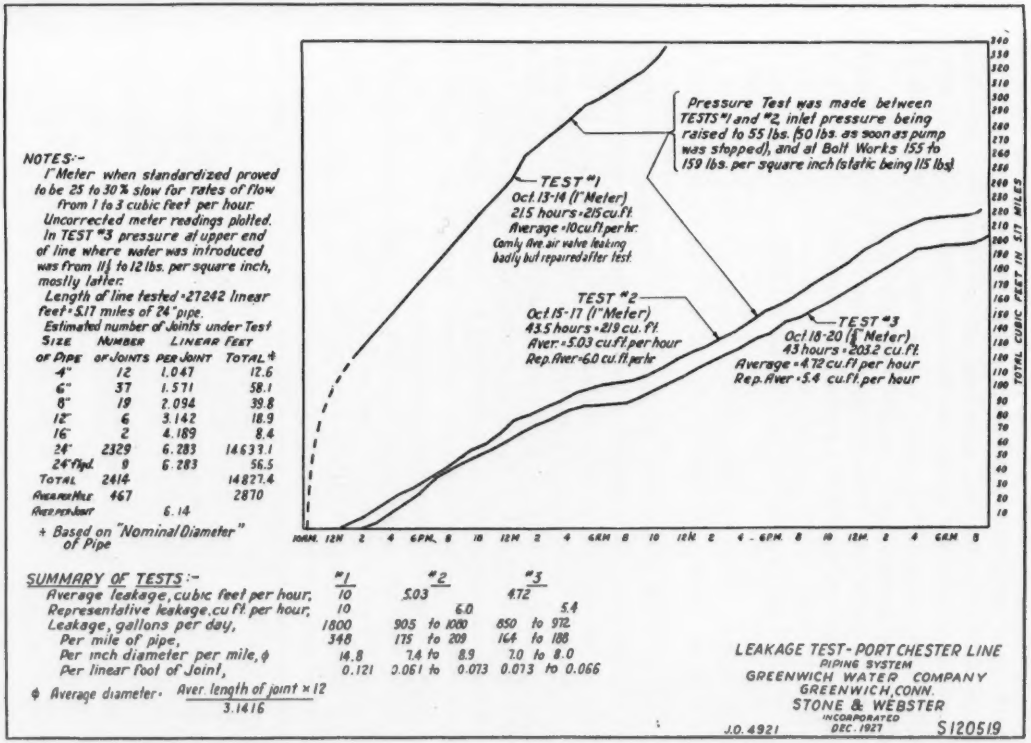
A water test of 150 per cent. of the static was first specified, and in the event that it was necessary to use the air-testing method, it was specified that from 60 to 70 per cent. of the water test pressures should be used. Under the air test, the joint was painted with soap suds made from Lux soap. At any point where bubbles occurred the joint was recaulked until tight.

Where there was water in the trench, a leak under water was easily found, whereas with the water test it would have been necessary to pump out the trench before testing. Furthermore, the contractor had a dry trench in the usual case after testing with air, whereas with the water test, the water had to be disposed of before proceeding with work on the next section. With an air compressor in use for caulking, it was a simple matter to pump air through the test plug.

One difficulty at first encountered was in making the test plug tight against air leakage. This was overcome by leading in the plug and later cutting it out. No gaskets experimented with were found satisfactory with the standard plug which has a tendency under pressure to spring at the contact edges.

The general conclusions reached from the air tests were that a pressure of not less than 30 lb. per sq. in. should be used in all cases, that generally speaking from 50 to 70 per cent. of the static pressure was satisfactory, and that the maximum pressure used should not exceed about 110 lb. per sq. in. as being the highest obtainable pressure from the usual air compressor available for pipe-line work, the joints passing the test of the latter pressure being satisfactory at least up to the static head of about 300 ft. encountered on this job. Difficulties increased in obtaining higher air pressures. Air will show through a joint where water will not, and an air test is therefore much more severe than a water test.

It is to be admitted that the one objection to the air test is that the pipe itself may in some instances not be subjected to a high field pressure


NOTES:-
1" Meter when standardized proved to be 25 to 30% slow for rates of flow from 1 to 3 cubic feet per hour. Uncorrected meter readings plotted.
In TEST #3 pressure at upper end of line where water was introduced was from 11½ to 12 lbs. per square inch, mostly latter.
Length of line tested = 27242 linear feet = 5.17 miles of 24" pipe.
Estimated number of Joints under Test

Size or Pipe	Number of Joints	Linear Feet per Joint	Total *
4"	12	1.047	12.6
6"	37	1.571	58.1
8"	19	2.094	39.8
12"	6	3.142	18.9
16"	2	4.189	8.4
24"	2329	6.283	14633.1
24" Flgd.	9	6.283	56.5
Total	2414		14827.4
Average per Mile	467		2870
Feet per Joint		6.14	

* Based on "Nominal Diameter" of Pipe
Pressure Test was made between TESTS #1 and #2, inlet pressure being raised to 55 lbs. (50 lbs. as soon as pump was stopped), and at Bolt Works 155 to 159 lbs. per square inch (static being 115 lbs.)
TEST #1
Oct. 13-14 (1" Meter)
215 hours = 215 cu. ft.
Average = 1.0 cu. ft. per hr.
Comly Ave. air valve leaking badly but repaired after test.
TEST #2
Oct. 15-17 (1" Meter)
43.5 hours = 219 cu. ft.
Aver. = 5.03 cu. ft. per hour
Rep. Aver. = 6.0 cu. ft. per hr.
TEST #3
Oct. 18-20 (1" Meter)
43 hours = 203.2 cu. ft.
Average = 4.72 cu. ft. per hour
Rep. Aver. = 5.4 cu. ft. per hour
10 AM. 12 M. 2 4 6 P.M. 8 10 12 M. 2 4 6 A.M. 8 10 12 M. 2 4 6 P.M. 8 10 12 M. 2 4 6 A.M. 8
TOTAL CUBIC FEET IN 5.17 MILES
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260 270 280 290 300 310 320 330 340
SUMMARY OF TESTS:-

	#1	#2	#3
Average leakage, cubic feet per hour,	1.0	5.03	4.72
Representative leakage, cu. ft. per hour,	1.0	6.0	5.4
Leakage, gallons per day,	180.0	905 to 1080	850 to 972.
Per mile of pipe,	34.8	175 to 209	164 to 188
Per inch diameter per mile, ϕ	14.8	7.4 to 8.9	7.0 to 8.0
Per linear foot of Joint,	0.121	0.061 to 0.073	0.013 to 0.066

ϕ Average diameter = Aver. length of joint × 12 / 3.1416
LEAKAGE TEST - PORT CHESTER LINE
PIPING SYSTEM
GREENWICH WATER COMPANY
GREENWICH, CONN.
STONE & WEBSTER
INCORPORATED
J.O. 4921 DEC. 1927 S120519

FIG. 3.

test after laying. To obviate this, the inspection of the pipe in the foundry and after delivery should be unusually rigid, and where possible the completed pipe line should be subjected to the customary water tests.

A summary of the results obtainable by air testing is given in Fig. 3, which shows the data obtained from a very severe water test made on a section of the main line 5.17 miles long, up and down hill. Some sections received a pressure test of between 400 and 500 per cent. under this test, instead of the usual 150 per cent. It should be noted that the leakage was only a small amount of that usually specified as a limit.

Water tests of the Glenville branch lines laid with Lead Hydro-tite joints also showed the following satisfactory results:

Test.	Linear Feet.	Gal. per Day per Linear Foot of Joint.	Days Healing.
1.....	1 195	1.21	6 to 34
2.....	679	0.15	....
3.....	189	0.53	14 to 18

Since placing in operation, two failures of deLavaud pipe have occurred.

Another interesting feature of the work was the cement lining of the pipe. A considerable quantity of the earlier shipments from the Bessemer plant was rejected because of loose spots, thin lining and shrinkage cracks. No pipe was accepted having a loose spot larger than 12 in. in diameter. Experimental treatment of shrinkage cracks did not prove satisfactory, the best treatment apparently being grout and water glass. Burning out joints will destroy the cement lining over adjacent areas, so that it is preferable to remove defective joints with a cold chisel.

The ordinary standard specifications for cement lining were followed. These have been presented by Charles W. Sherman in the JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION, Vol. 40, page 104. Subsequently, after encountering the above-mentioned difficulties, the required thickness was decreased to that sufficient to cover well all rough spots on the iron itself. This resulted in much improvement in the character of the lining. Our modified specifications put the responsibility squarely up to the manufacturer to produce a lining free from objectionable loose spots and shrinkage cracks, and adhering tenaciously.

The only variation from the usual specification for the pipe itself was in respect to the chemical composition, as follows:

	Percentage Content.	
	Maximum.	Minimum.
Sulphur.....	.10	....
Phosphorous.....	.90	....
Manganese.....	.55	.35
Silicon.....	2.00	1.60

The pipe was furnished by the U. S. Cast Iron Pipe and Foundry Company, who coöperated in excellent fashion throughout the job.

Notes Regarding Construction. Before installing end anchors, deflection tests on a flanged overhead crossing of the Byram River indicated a maximum deflection of $\frac{3}{16}$ in. at static pressure of 133 lb. per sq. in., and $\frac{5}{16}$ in. at a static pressure of 154 lb. An expansion joint opened up at the same time $\frac{5}{16}$ in. The pipe was strapped to a special steel supporting-truss which moved with the pipe, the ends being raised slightly from the abutments. After the heavy concrete anchor blocks were placed at the bends at each end of the crossing, there was no movement at any pressure. This is mentioned as a possible answer to some recent failures, as reliance should not be placed on the anchoring effect of the adjacent earth even with an expansion joint in the center of the span. Continued movement of the pipe may cause deterioration of adjacent joints through a breathing action. For a similar reason, concrete thrust-blocks were placed at all points where an abrupt angle occurred.

A premixed gravel aggregate furnished by Henry Steers, Inc., from Long Island, graded from sand to 1½-in. gravel, was used for all concrete work, as this material could be obtained at much less expense than separate shipments of sand and gravel or crushed stone. This probably resulted in a slightly higher cement content than would have been obtained with separate aggregates of equal quality carefully proportioned at the job. However, the cost of the slight increase in cement necessary to maintain the desired consistency of concrete and counteract variations in the grading of the aggregate, due to the tendency of the material to segregate in handling and shipping, was much less than would have resulted from the more expensive separate aggregates.

At the start of the job in Class A concrete (which was specified for all water-tight work) one sack of cement was used for 5½ cu. ft. of mixed aggregate. For Class C concrete (which was used for backfilling) one sack of cement was used with 9 cu. ft. of aggregate. About 3 lb. of Celite per sack of cement were used in Class A concrete.

Concrete tests were made continuously throughout the job, and the early strengths shown were so satisfactory that the concrete proportions were later changed to use about 10 per cent. less cement. These proportions, with the Celite, resulted in concrete of excellent workability so that practically no segregation of materials or honeycombing of the concrete was evidenced. Compression-strength tests averaged 2 500, 2 900 and 3 200 lb. per sq. in. at 14 days, 28 days and 2 months age respectively, although there was considerable variation in the strengths of individual tests due to variations in proportions, size of aggregate in test specimens and curing conditions.

For the underground brick walls of the temporary end of the building, a Portland cement mortar was used with from 5 to 8 lb. of Celite per bag of cement. This mortar was much easier to handle than a straight cement mortar but was not so economical or so satisfactory to work as the cement and hydrated-lime mortar used in the brickwork above ground.

Any statement as to the actual construction periods for the several main items of work involved is subject to some misinterpretation, because several extensions to the contract were authorized which materially changed the original scope of work. If authorization had been received at the beginning, the construction period could have been shortened. There was also trouble in the cement lining in the first pipe delivered which necessitated its return to the manufacturer with the resultant delay in starting the pipe-line work. One strike of short duration occurred in connection with the pipe-line work in Connecticut. A long delay also resulted in acquiring necessary land for the Purification Plant, its purchase not being consummated until four and a half months after the award of the construction contract.

The following table gives the essential contract dates, subject to the above causes of delay:

PROGRESS OF CONSTRUCTION.

1926.	
December 2.	Contract for construction awarded.
December 30.	Contract for pipe awarded to U. S. Cast Iron Pipe & Foundry Company.
1927.	
January 20.	Metcalf & Eddy authorized to proceed with design of Purification Plant.
January 21.	Subcontract for pipe lines in New York awarded to Daly & Merritt, Inc.
January 24.	First carload of 20-in. pipe received.
February 4.	Pipe-line excavation started in New York.
February 26.	Subcontract for pipe lines in Connecticut awarded to Peter Mitchell, Inc.
February 28.	First pipe joint poured in New York lines.
March 14.	Pipe-line work in Connecticut started.
April 18.	Notification received of purchase of land at Purification Plant, permitting start of active work at Purification Plant.
August 6.	Started pouring concrete in filter house.
August 16.	Pipe line completed Glenville Road to Willet Avenue.
August 27.	Cutting 30-in. intake main, construction of by-pass and work on yard interconnections.
September 9.	Pipe lines in New York completed.
September 20.	Commenced laying brick.
October 3.	Glenville Road branch started.
October 4.	Ceremony of pouring last joint in main pipe line.
October 11.	Pipe line to Connecticut-New York line filled. Authorized to construct two additional filters.
October 21.	Main pipe line from Purification Plant to Port Chester placed in commercial use.
	Laying of Glenville Road branch pipe line started.
October 22.	Started pouring concrete in pump house.
October 31.	Restoration of roadways in New York completed.
November 19.	Finished concrete work of Coagulation Basins.
November 22.	Connecticut pipe trench backfilled and graded.
December 5.	Water turned into branch line to Glenville Post Office.
December 14.	Glenville line completed.
December 23.	Glenville branch line put into commercial service.

1928.

January 5.	Official opening of Glenville branch pipe line.
January 13.	Started dismantling concrete plant.
January 28.	Glenville branch lines backfilled and graded.
February 25.	Second filter extension authorized.
April 26.	New filter plant placed in commercial service.
July 1.	Purification Plant completed.
August 1.	All minor changes and alterations completed.
August 18.	Last construction men off job.

The maximum number of men employed on the work in any one day totaled 235.

THE NEW PURIFICATION PLANT OF THE GREENWICH WATER COMPANY.

BY E. SHERMAN CHASE.*

[*Read September 19, 1928.*]

In line with a policy of providing an adequate supply of water of high quality, the Greenwich Water Company, under the guidance of its president, Eben F. Putnam, has recently constructed and placed in operation a modern water purification plant. This plant consists of a low-lift pumping station, aërators, chemical mixing tanks, coagulation basins, rapid sand filters, clear-water basin and chlorination equipment.

As constructed the coagulation basin has a rated capacity of 6 m.g.d., while the filters will yield 4 m.g.d. The clear-water basin has a storage of 1 million gal. The coagulation basin has excess capacity in order to permit its use in conjunction with existing pressure filters. The plant is so laid out as to be capable of ultimate expansion to 8-m.g.d. capacity.

Sources of Supply.†

The principal sources of supply of the Greenwich Water Company are two reservoirs known as Putnam and Rockwood lakes. These reservoirs are connected and have a common tributary watershed 4.65 sq. miles in area, including the area of a small stream, Pipen Brook, which is diverted to Rockwood Lake. An emergency supply is available by pumping from the Mianus River to Rockwood Lake. The drainage area of this river above the emergency intake is about 17 sq. miles. To the west of Putnam and Rockwood lakes, another reserve supply is available from the east branch of the Byram River. Diversion is accomplished by means of a low concrete dam from which a tunnel leads to Putnam Lake. The drainage area above the point of diversion is about 4 sq. miles.

The watershed tributary to Putnam and Rockwood lakes is sparsely inhabited and comparatively free from sources of contamination. The water company owns the land around the lakes and maintains a sanitary oversight of the reservoirs and adjacent lands. The resident population on the watershed is relatively remote from the reservoirs and tributary water courses. As is true of all surface sources whose catchment areas are inhabited or traversed by highways, some possibility of chance pollution exists.

The opportunities for pollution of the Mianus River are somewhat greater than is the case with the lakes. Although the stream flows for

*Of Metcalf & Eddy, Engineers, Boston, Mass.

†Description of the sources of supply and the distribution system is the subject of the preceding paper by Dana M. Wood.

some 4 or 5 miles above the intake through a narrow valley with steep, wooded and uninhabited side slopes, there are farther upstream the small villages of Bedford, N. Y., and Banksville, Conn. Neither of these villages has a sewerage system, so there is no direct discharge of sewage into the stream.

The Byram River watershed above the point of diversion is largely cleared land devoted to agriculture with small scattered areas of woodland. A few houses are located upon this watershed and the resident population is small. The houses in general are situated well back from the stream and the sanitary conditions are good.

Rules and regulations for the sanitary protection of those portions of the watersheds lying within the State of New York and tributary to the water supply of the Greenwich Water Company were enacted by the New York State Department of Health in 1927.

Putnam Lake is formed by an earth-embankment dam with masonry core wall. Its total capacity, when full to spillway crest, is 572 million gal. The intake is located in this reservoir and consists of a concrete well with screens and inlet openings through which reservoir water can be drawn at three different levels, namely 5, 16 and 27 ft. below high-water level. A blow-off is also provided from the bottom of the reservoir. Rockwood Lake has a capacity when full of 500 million gal. Pipen Brook Reservoir has a capacity of 14 million gal.

Old Pressure Filters.

Until the construction of the new gravity rapid sand filter plant, the water drawn from Putnam Lake was treated with liquid chlorine and passed through pressure mechanical filters. About 1 m.g.d., after chlorination, was by-passed around the filters and delivered by separate pipe line to the power plant of the N. Y., N. H. & H. R. R. at Cos Cob. The filtered water was delivered by gravity to the distribution systems of Greenwich, Port Chester and adjacent territory.

The chlorination equipment consisted of two automatic-control dry-feed chlorinators made by Wallace & Tiernan Co., the apparatus being housed in a small stone building over a 30-in. main leading from Putnam Lake about one-quarter mile distant. This building also housed the equipment for applying coagulant to the water prior to filtration and the recording apparatus for the Venturi meter on the 30-in. line. The chlorine was applied in advance of the Venturi meter, the coagulant following it. The apparatus for applying coagulant consisted of "alum pots" of the usual type, and the period of time available, for the reaction to occur and floc to form prior to filtration, was but a few minutes.

The filter plant consisted of two horizontal pressure filters each 8 ft. in diameter by 20 ft. long and twelve vertical filters each 10 ft. in diameter by 10 ft. high. The rated capacity of these filters was about 4.0 m.g.d.

New Gravity Filters.

In view of inadequate capacity of the pressure filters and the difficulty inherent with this type of filter in securing a satisfactory effluent, particularly in the absence of settling basins, it was decided by the Greenwich Water Company to increase its filter capacity by the construction of gravity type, rapid sand filters at Putnam Lake. (Fig. 1.) A description of this new plant follows:*

Intake and Low-Lift Pumping Station. The existing Putnam Lake intake serves the new plant through a branch of the 30-in. pipe which

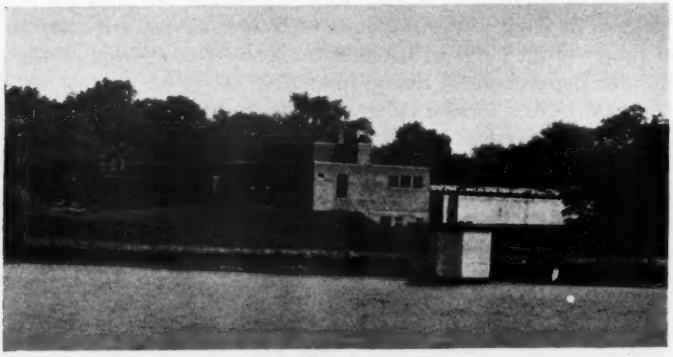


Fig. 1.

originally served the pressure filters directly. In order to increase available storage and to provide adequate head after filtration, the filter plant was placed above high-water level on the side hill just downstream from the reservoir, and a low-lift pumping station was provided.

This pumping station is a one-story brick structure with a main pump room 22 ft. by 42 ft. inside with two wings approximately 11 ft. by 14 ft. inside. In one wing emergency chlorine equipment is provided for treating raw water should it ever be necessary to by-pass the filter plant. In the other wing there are toilet facilities and in the basement are located the heating equipment and a coal bunker.

The pumping equipment comprises two motor-driven, horizontal centrifugal pumps. The pumps were manufactured by the Warren Steam Pump Company with rated capacities of 8 m.g.d. each. Reservoir water comes to the pumps under a gravity head of about 20 ft. with full reservoir, the head varying according to water level in the reservoir. The raw water is pumped to the filter plant, either to aërating nozzles or to the chemical mixing tanks. Regulation of pumping is secured by means of a butterfly valve in the discharge line, automatically controlled by the water level on

*See Fig. 2, "The New Water-Works System of the Greenwich Water Company" by Dana M. Wood, for general arrangement of the plant.

the filters. As the water level over the filters rises, the valve closes, thereby increasing the friction head against the pumps and reducing the discharge, the reverse being the case with falling water level on the filters. Variable speed control is also provided for the pumps to permit of economical operation. A Venturi meter is installed on the 24-in. raw water discharge from the pumps, and a recording indicator register is located in the office of the chemical house.

Aëration. Aëration is provided by 48 Sacramento-type nozzles located on the roof of the coagulation tanks. These nozzles are symmetrically

FIG. 2.

placed in a grid of cast-iron pipe raised on concrete piers above the roof. There are 6 rows of 8 nozzles each. The sprayed water falls upon the roof and thence drains to a conduit leading to the chemical mixing tanks. The nozzles have 2-lb. cones and throw a spray approximately 17 ft. in diameter with a nozzle head of about 5 ft. Three sides of the aëration roof are surrounded by a fence of corrugated zinc 7 ft. 6 in. high. On the fourth side are the control valves and walkway. (Fig. 2.)

Chemical Mixing Tanks. There are two tanks in which the aërated water receives the dose of chemicals. These tanks are 18 ft. square in plan and carry a water depth of 17.5 ft. Adequate mixing is secured by mechanical stirrers consisting of wooden paddles operated by electric motors and so geared to these motors as to revolve at a rate of about one revolution per minute. (Fig. 3.) Interchangeable sets of gears are also provided for other speeds. With the plant operating at its ultimate capacity of 8 m.g.d. these tanks give a total mixing period of approximately 15 minutes. Each tank is provided with 24-in. inlet and outlet and with a 12-in. drain.

For application of chemicals there are three motor-operated No. 3 Gauntt dry-feed machines, and space is provided for a fourth. The chemicals used are ordinary filter alum (aluminium sulphate) and soda ash. The dry chemicals are fed to the machines through hoppers from the chemical storage room on the floor above. In the two alum machines a stream of water mixes with and dissolves the chemical, and the solution thus made is fed by gravity through rubber hose to the water entering the mixing basins. The soda ash is applied in a similar way to the filtered water as it leaves the filtered-water reservoir. It serves to neutralize the increase in acidity

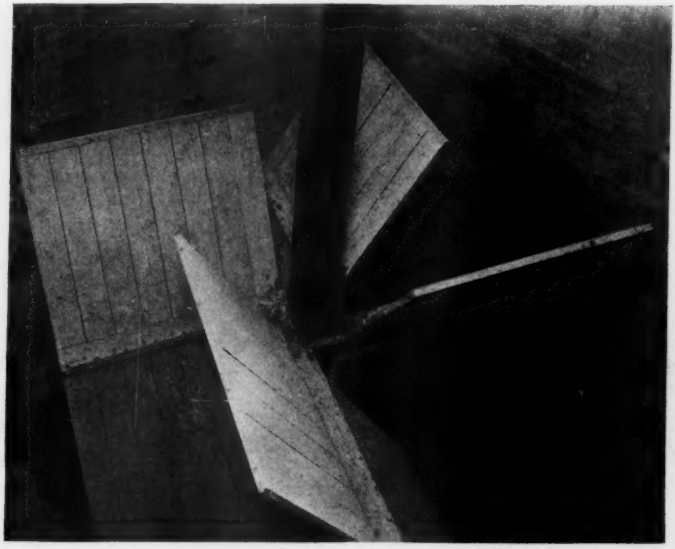
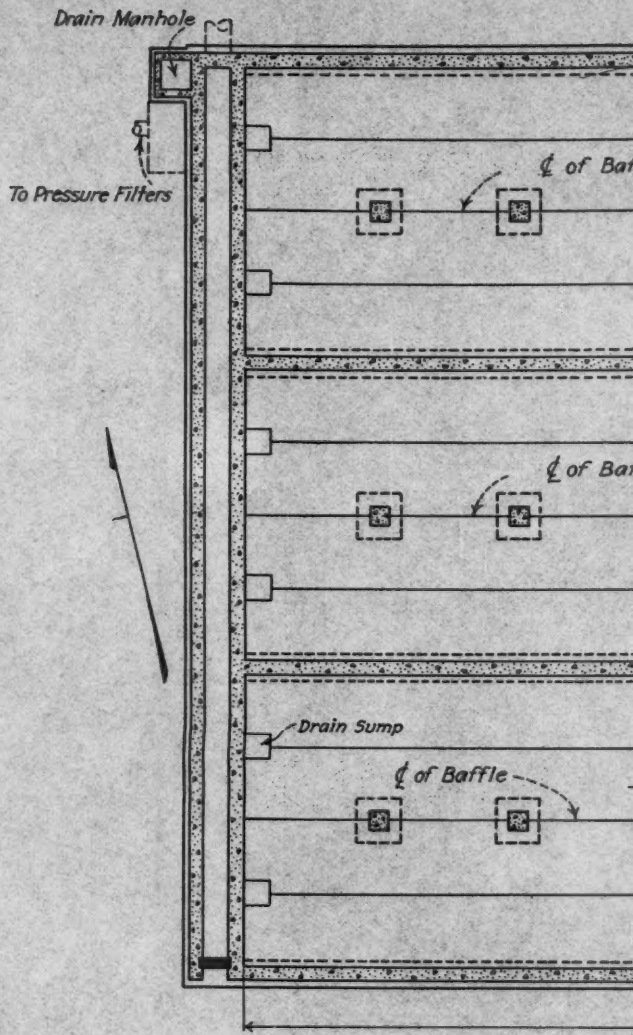


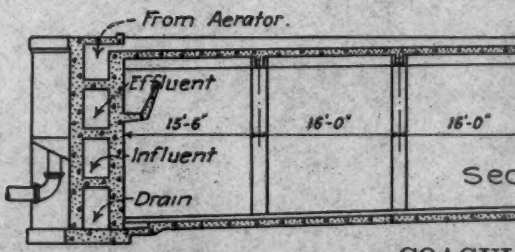
FIG. 3.

brought about by the use of alum. The chemical-feed machines have been calibrated, and control of chemical application is very accurate. If it proves necessary in the future, the fourth chemical-feed machine can be installed for adding soda ash to the raw water, although generally the raw water contains adequate alkalinity to react with the alum. (Plate II.)

Settling Basins. There are three settling basins or rather one basin divided into three separate compartments by partition walls. Each compartment is 95 ft. long by 33 ft. wide inside, with a central, longitudinal baffle wall of plank around which the treated water flows before passing over outlet weirs to a channel leading to the filters. (Plate I.)

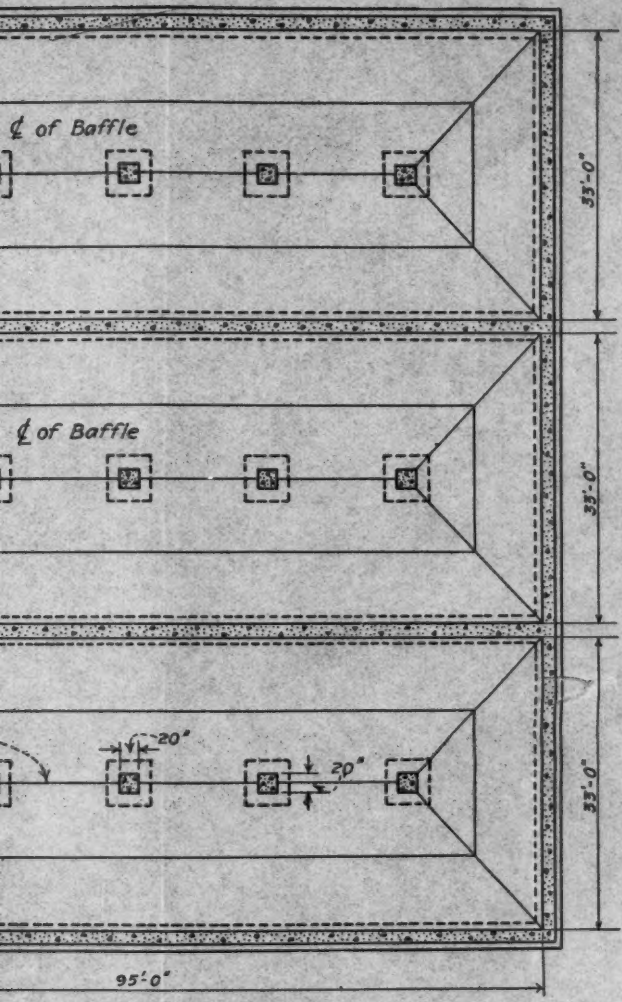
The basin is covered by a flat slab roof supported on 15 columns. The maximum water depth varies from 14 ft. to 16 ft. 6 in. as the floor pitches to 12-in. drains. The distance between water level and underside of


Drain Manhole
To Pressure Filters
℄ of Baf
℄ of Baf
Drain Sump
℄ of Baffle

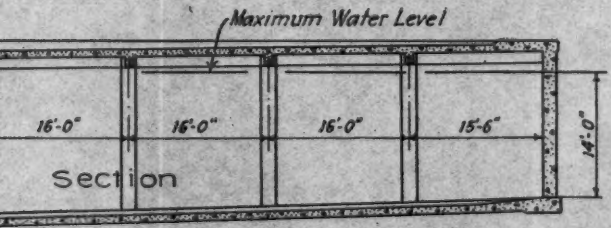

From Aerator.
Effluent
15'-6"
16'-0"
16'-0"
Influent
Drain

COAGUL

PLATE I.
N. E. W. W. ASSOCIATION.
VOL. XLII.
CHASE ON
GREENWICH
PURIFICATION PLANT.



Plan.



Section

COAGULATION BASIN

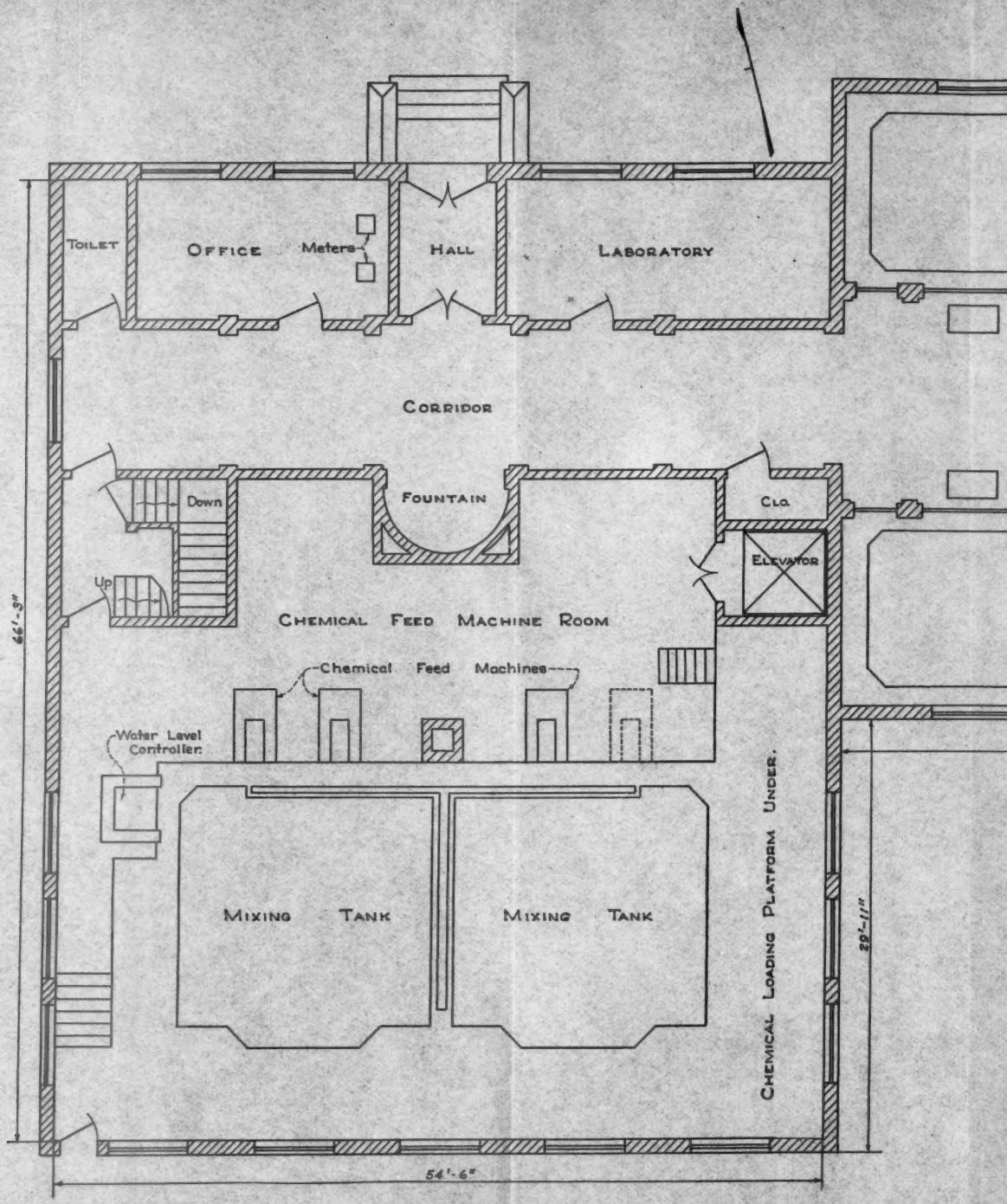
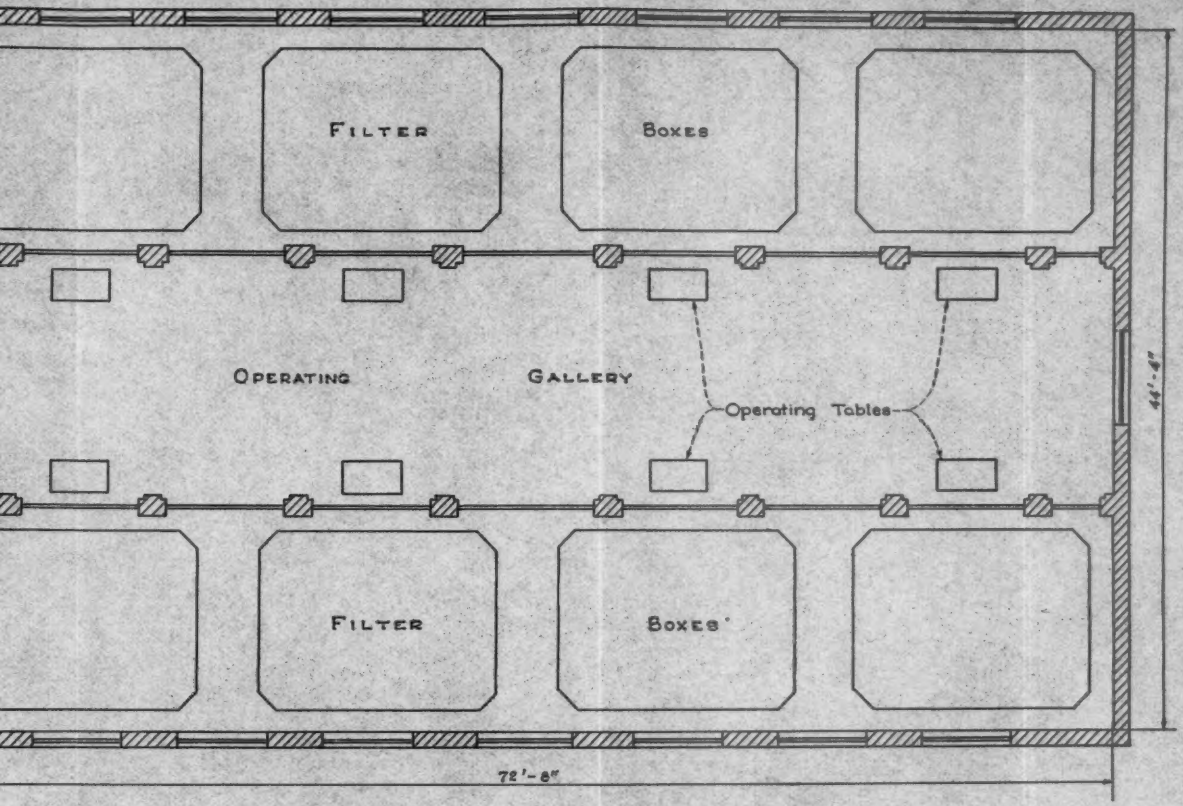

TOILET
OFFICE
Meters
HALL
LABORATORY
CORRIDOR
Down
FOUNTAIN
CLO.
ELEVATOR
Up
CHEMICAL FEED MACHINE ROOM
Chemical Feed Machines
Water Level Controller
MIXING TANK
MIXING TANK
CHEMICAL LOADING PLATFORM UNDER.
66'-3"
29'-11"
54'-6"

PLATE II.
N. E. W. W. ASSOCIATION.
VOL. XLII.
CHASE ON
GREENWICH
PURIFICATION PLANT.



CHEMICAL HOUSE
AND
FILTER GALLERY.

Each filter unit contains two wash-water troughs of steel, 16 in. wide and painted. The tops of the troughs are 2 ft. 6 in. above the surface of the sand.

Wash water from the clear-water basin is provided by two motor-operated, automatically primed, centrifugal pumps discharging directly to the filter underdrains through a 16-in. pipe. These pumps each have a capacity of 4 m.g.d. One pump at a time is operated for filter washing and is started and stopped by push-button control in the operating gallery. The normal vertical rise of wash water over the filters is 24 in. per minute.

Clear-Water Basin. The clear-water basin is a covered reinforced concrete structure 74 ft. wide by 150 ft. long inside dimensions with a maximum water depth of 12 ft. 6 in. equivalent to a capacity of 1 million gal. (Fig. 5.) The whole basin is covered by a slab roof supported by three rows of columns. The roof pitches to its perimeter around which is a low concrete wall so that a secondary aërator for filtered water can be installed if experience shows the necessity for such installation. (Plate IV.)

The corner of the basin nearest the filter house is partitioned off forming a compartment about 17½ ft. by 36½ ft. This compartment is also divided in halves along its length by a wooden partition. The object of this compartment is to provide an ample reaction period for the chlorinated filter effluent before mixture with stored water. An electric light is installed at the bottom of this compartment so that observations can be made of the turbidity of the filtered water.

Inlet and outlet pipes are 24 in. in diameter. In addition a 6-in. drain leads from one end of the basin to the main drain from the filters. In one corner of the reservoir is an 8-in. vertical riser which contains the water-level gage.

Chemical House. The chemical or head house consists of a main building of two stories and basement and two wings of one story and basement. A third wing will be added when more filters are built.

The first floor of the main building contains the entrance vestibule, corridor, office, laboratory and toilet facilities. An ornamental fountain in this corridor faces the entrance. (Fig. 6.) One wing of the building covers the filters and operating gallery under which is the pipe gallery. The other wing covers the chemical mixing tanks and appurtenances.

The basement of the main building contains the wash-water pumps and motors, a service pump, heating boiler, coal bunker, locker room, toilet, domestic water supply and elevator machinery. From one side of the main basement the filter-pipe gallery leads and from another side a gallery extends around the chemical mixing tanks.

The second floor contains the chemical storage room and chlorine room. The chlorine room houses two vacuum-type Wallace & Tiernan chlorinators for applying chlorine to the filtered water prior to entrance to the clear-water basin. An electrically-operated service elevator runs from the basement to the second floor.

Pipe Gallery. The pipe gallery is 14 ft. wide by 16 ft. high. The uppermost pipe is the 20-in. settled-water pipe from which 8-in. branches lead to each of the filter units. Next below is the 16-in. wash-water pipe with 16-in. branches to the filters. Beyond the wash-water pumps and on

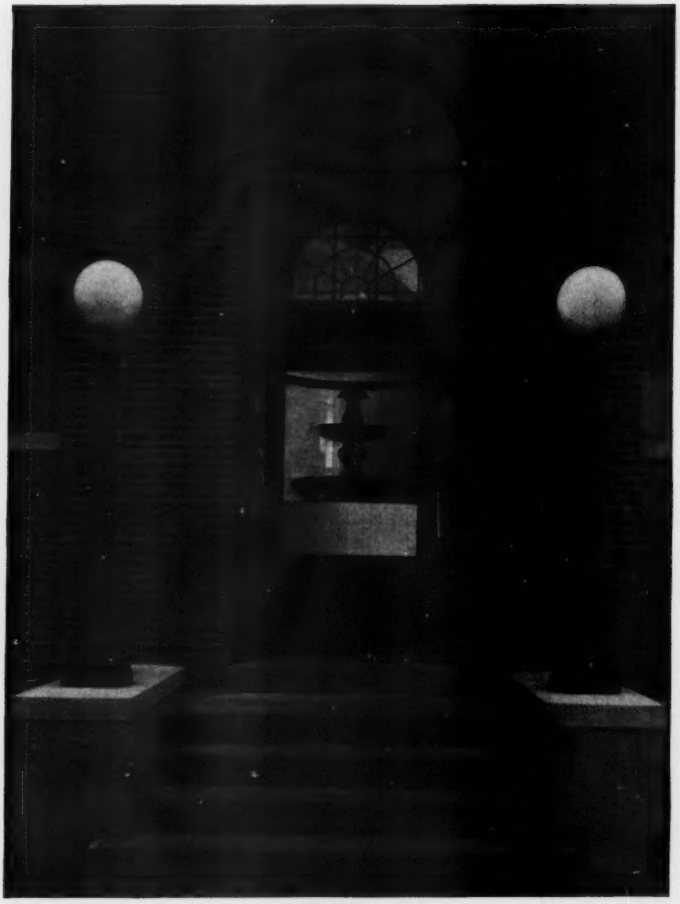


FIG. 6.

this 16-in. line is a wash-water rate-controller tube with indicating, recording and registering apparatus in the office. Below the wash-water pipe is the filtered-water pipe, 20 in. in diameter from which 6-in. branches lead to 20-in. headers from the filter underdrains. Builders Iron Foundry rate controllers are located on each of these 6-in. branches. The lowermost pipe is an 18-in. tile drain, surrounded by concrete, on which are concrete

junction boxes which in turn connect with the inlet compartments of the filter boxes through 16-in. pipes. Four-inch by-pass pipes permit filtering to waste into the drain. All pipes are provided with the necessary hydraulically-operated valves controlled from operating tables on the floor above. A plank walk extends along the gallery just above the filtered-water pipe. Sampling cocks are provided on each filter outlet. The chlorination apparatus is connected to the 20-in. filtered-water pipe ahead of the clear-water basin shortly before the pipe leaves the basement of the chemical house.

Special Features. In designing the plant, an attempt has been made to reduce the amount of supervision required in the operation of the various parts. Several automatic and remote-control features have been installed for this purpose which deserve a short description.

The low-lift pumps are equipped with slip ring motors which permit of adjustable speed control. Extension relay-circuits for the control apparatus have been placed in the office of the chemical house and the speed of the pumps may be controlled from either the chemical house or low-lift pumping station.

As previously referred to, a special apparatus consisting of a float differential-mechanism, 4-way valve and pilot valve, controlled by the water level on the filters, regulates the flow through the plant by throttling the discharge of the low-lift pumps.

The necessary valves controlling the inlet, outlet, wash water and drain ports of the filter units have been made to operate hydraulically from hand levers on the operating tables. This permits all necessary valves to be operated on the table top in front of each unit.

Instead of the usual wash-water tank for washing the filters, there have been installed duplicate wash-water pumps. These pumps may be started and stopped from a push-button station in the filter wing. There are also telltale lights in the operating gallery to indicate which pump is running.

An automatic priming device has also been included which keeps the pumps primed at all times or, on failure of the priming system, throws out the electrical circuit so that the pumps cannot be started until the priming is complete.

In addition, a rate controller has been placed on the discharge of the pumps which automatically holds the rate of washing on the filters constant.

An annunciator has been placed in the office with connections indicating high and low water in the filtered-water reservoir. Low pressure is also indicated in the domestic water-supply system which furnishes motive power for the hydraulic valves. The annunciator operates an industrial howler.

Interconnecting telephones have been installed between the chemical house, low-lift pumping station and the old pressure-filter plant. In addition, there is a public telephone connection to take care of emergency calls from various parts of the distribution system.

Miscellaneous. For service water for flushing, lawn sprinkling and other general but intermittent uses, a 250-g.p.m., motor-driven, centrifugal pump and piping system to points of expected use have been provided.

A surface drain removes condensation and leakage collecting in the basement of the chemical house.

Water supply for the laboratory, toilets and operation of hydraulic valves is obtained from small, pneumatic-pressure tank systems installed in duplicate. The tanks are of 500 gal. capacity each, water from the clear-water basin being pumped into them by 50-g.p.m. centrifugal pumps. A pressure switch has been installed on the domestic supply pumps to permit the pumps to start when the pressure in the pneumatic storage tanks falls below a certain limit and to stop the pumps when the proper pressure is restored to the system. A small air compressor is also provided for adding air to the tanks from time to time.

The sewage from the toilets of pumping station and filter plant is discharged into leaching cesspools. The wash water and other drainage is discharged into the stream below the reservoir.

Operation. The filter plant was first put into regular operation the latter part of April, 1928. It is operated under the general supervision of W. Jay Willson, superintendent of the Greenwich Water Company, and under the direct supervision of Mr. Harold C. Chandler, chemist-in-charge, who was formerly chemist at the Cambridge, Massachusetts, filter plant.

During the period of tuning up, some trouble was experienced with the water-level controller regulating the discharge from the low-lift pumps. This trouble was remedied by changing the gearing connected to the cam that operates the pilot valve controlling the hydraulically-operated butterfly valve in the discharge pipe from the pumps.

Filter runs between washings were also unduly short during the first few weeks. Increasing the rate of washing the filters to about 30 in. vertical rise per minute and scraping off the top 2 in. of fine material resulted in an improvement in filter runs. Copper-sulphate treatment of Putnam Lake also may have been of some value in destroying microscopic organisms that in reaching the filters in any quantity would tend to decrease filter runs.

An interesting feature of the purification plant is the operation of the old pressure filters in parallel with the new gravity filters. The preliminary treatment of the raw water by coagulation and settling at the new plant, prior to the application of this water to the pressure filters, has brought about a marked improvement in the quality of the effluent from these filters. Inasmuch as it was desired to prevent any increase in corrosive properties of the filtered water, recourse has been had to the application of soda ash to the filtered water. This application is made by one of the dry-feed chemical machines at the new plant to the water drawn from the clear-water basin. The water from the basin flows by the old filter plant in the

TABLE 1.

SUMMARY OF OPERATION AND CHEMICAL TREATMENT COMPILED FROM MONTHLY AVERAGES OF DAILY RESULTS, MAY TO AUGUST, 1928.

	Volumes of Water (mill. gal.).			Gravity Filters.						Pressure Filters.		Rate of Chemical Application.		
	Filtered by gravity.	Filtered by pressure.	Total delivered to mains.	Rate (mill. gal. per acre per day).	Length of runs (hours).	Average time of washing (min.).	Wash water (%).	Average loss of head (ft.). Initial.	Average loss of head (ft.). Final.	Average time of washing (min.).	Wash water (%).	Alum. (grains per gal.)	Soda. (grains per gal.)	Chlorine (p.p.m.).
May														
Average	2.61	3.82	6.57	124	8.6	2.5	7	2.2	10.0	2.5	2	.85	.55	.52
Maximum	2.91	5.17	7.63	145	17.8	3.0	10	2.9	10.8	3.0	4	1.20	.72	.86
Minimum	2.22	2.47	5.94	117	5.7	2.0	4	1.7	9.0	2.5	1	.60	.38	.33
June														
Average	2.84	3.20	6.20	129	9.7	3.0	5.6	2.1	9.2	3.0	3	.84	.65	.53
Maximum	3.82	3.98	6.95	132	14.3	4.0	12	2.7	10.3	3.5	4	1.05	.87	.76
Minimum	2.28	1.82	5.10	126	6.7	2.5	3	1.8	8.4	2.5	3	.70	.46	.40
July														
Average	3.70	2.64	6.05	131	10.8	2.5	5	2.2	9.0	3.0	3.8	1.07	.67	.56
Maximum	4.00	4.02	6.89	134	15.7	3.0	9	2.6	9.8	3.0	6	1.40	.87	.69
Minimum	3.07	1.65	5.16	130	8.3	2.5	4	1.9	8.2	2.5	2	.70	.49	.47
August														
Average	3.69	2.37	5.77	134	11.0	2.5	4.5	2.3	9.1	3.0	4.2	1.10	.76	.54
Maximum	4.09	3.74	6.96	134	12.9	2.5	6	2.7	10.6	3.0	7	1.40	.99	.71
Minimum	3.31	1.49	5.11	134	8.8	2.5	3	2.0	8.4	3.0	3	.80	.52	.43

TABLE 2.

SUMMARY OF PHYSICAL, CHEMICAL AND BACTERIOLOGICAL ANALYSES COMPILED FROM MONTHLY AVERAGES OF DAILY RESULTS, MAY TO AUGUST, 1928. (Results expressed in parts per million, unless otherwise stated.)

	Turbidity.			Color.			Alkalinity.			Carbon Dioxide.			pH Value.				Bacteria per cc.							
																	Gelatine at 20° C.				Agar at 37° C.			
	Raw water.	Settled water.	Delivered water.	Raw water.	Settled water.	Delivered water.	Raw water.	Settled water.	Delivered water.	Raw water.	Settled water.	Delivered water.	Raw water.	Settled water.	Delivered water.	Raw water, temperature (°F.).	Raw water.	Settled water.	Filtered water.	Delivered water.	Raw water.	Settled water.	Filtered water.	Delivered water.
May																								
Average	3	1	0	22	12	2	11.5	5.5	11.0	1.5	7.5	4.0	7.35	6.45	6.85	58	160	220	950	2	40	23	140	1
Maximum	4	3	1	26	18	7	12.0	7.0	14.0	2.0	8.5	6.5	7.80	6.60	7.25	65	240	500	1 500	7	170	170	350	4
Minimum	2	1	0	19	7	0	10.0	2.5	5.0	1.0	6.0	2.0	7.15	6.10	6.30	50	90	80	300	0	17	3	8	0
June																								
Average	3	2	1	23	14	4	12.0	5.5	12.5	1.5	7.0	3.5	7.30	6.40	6.95	..	800	550	1 000	5	90	140	90	2
Maximum	5	3	1	30	22	6	13.5	7.0	19.0	2.5	8.0	6.0	7.55	6.60	7.55	..	5 000	1 300	2 200	23	325	1 000	350	6
Minimum	3	1	0	18	6	1	10.5	4.0	5.0	1.0	6.5	1.0	7.00	6.20	6.45	..	60	80	325	0	7	5	2	0
July																								
Average	4	2	0	34	17	5	13.5	5.0	14.0	2.0	8.5	3.5	7.25	6.30	7.00	74	200	140	750	2	160	42	70	2
Maximum	6	4	1	55	35	9	15.5	7.0	19.0	3.5	10.0	6.0	7.50	6.50	7.30	77	350	190	1 700	4	1 300	120	250	9
Minimum	2	1	0	25	8	2	11.5	2.0	7.0	1.0	7.0	2.0	6.75	6.10	6.60	71	90	40	225	0	8	3	14	0
August																								
Average	2	1	0	24	11	3	14.0	6.0	17.0	1.5	8.0	3.0	7.40	6.40	7.10	..	...	...	...	..	65	350	400	2
Maximum	3	2	1	29	19	6	16.5	8.0	24.0	3.0	10.0	5.0	7.60	6.60	7.90	..	...	...	...	..	200	2 100	1 200	10
Minimum	2	1	0	18	6	2	11.0	3.0	9.5	1.0	6.5	0.5	7.10	5.95	6.70	..	...	...	...	..	14	4	75	0

30-in. pipe originally carrying raw water to these filters. Below the old filters, crossovers exist that permit mixing of the effluents from both old and new plants. By overdosing with soda ash the effluent of the new plant and by chlorinating it with the chlorine equipment formerly used for chlorinating the pressure-filter influent, the effluent of the pressure filters is corrected for corrosive qualities by the excess soda ash and disinfected by the chlorine carried in the effluent from the new plant. To apply soda ash directly to the pressure-filter effluent would require an additional chemical-feed machine and injector equipment. Direct chlorination of the pressure-filter effluent would have required further changing of equipment. The results obtained by the present method of operation appear to have been satisfactory.

Operation Data. Table 1 summarizes the essential operation data for the months of May, June, July and August, 1928. In general, the quantity of water treated by both filter plants has averaged about 3 m.g.d. each or 6 m.g.d. total. In the case of the new plant the average length of filter runs graduallyincreased from about 8½ hours in May to 11 hours in August. The pressure filters during this period have required washing but once daily. This has been due, in all probability, to the coarser sand in these filters. The percentage of wash water required has been approximately 5½ with the new filters and 3½ with the old. The higher percentage required for the newfilters has been largelyincidental to the tuning-up process. In August, the figures were 4.0 and 3.0 per cent. respectively. In general, the alum application has been at a rate of 0.9 grains per gal. and the soda ash application at a rate of 10 p.p.m. The chlorine dose has averaged about 0.5 p.p.m.

Operation Results. The combined filter plants have produced a clear, practically colorless and non-corrosive water. Turbidity has been reduced from about 3 p.p.m. to zero, and color from about 25 p.p.m. to 3 p.p.m. The pH of the delivered water has averaged about 7.0. Bacteria have been materially reduced. The average 20°C. gelatine counts have been about 500 per cc. in the raw water and 2 in the delivered water. The 37° C. agar counts have been reduced from 95 to 2 per cc. The raw water usually contains organisms of the *B. coli* type in 10 cc. inoculations and occasionally in 1 cc. At no time has the delivered water given confirmed tests for these organisms. In brief, the Greenwich Water Company is delivering a safe and attractive water. (See Table 2.)

The new purification works were designed by Metcalf & Eddy, and constructed by Stone & Webster, Inc. with Mr. Carlton F. Green, construction superintendent. The Greenwich Water Company is a subsidiary of the Community Water Service Company, of which Reeves J. Newsom is vice-president and chief engineer.

THE EFFECT OF SUNLIGHT ON THE DETERMINATION OF CHLORINE BY THE ORTHO-TOLIDIN METHOD.

BY F. R. McCRUMB AND W. R. KENNY.*

[*Read September 20, 1928.*]

The extensive use of chlorine in the treatment of water, sewage and industrial wastes makes it necessary to examine critically the analytical method used in determining residual chlorine. The method of analysis now employed most extensively is based on the fact that free chlorine yields a colored substance when treated with ortho-tolidin under the proper conditions. The resulting color is then compared with color standards representing definite concentrations of free chlorine.

In a previous paper one of us[1] described a comparator method that could be used with colored or turbid solutions and in the presence of certain interfering substances. At the same time it was pointed out that in order to secure a fairly stable color, comparable to the color standards used, the pH must not exceed a value of 2.0. Directions were given for the preparation of an ortho-tolidin reagent that would be stable and at the same time would give the proper conditions in testing water, sewage and trade wastes. The time of development of the "ortho-tolidin chlorine color" was investigated as well as the effect of light and temperature.

It had previously been reported[2] that direct sunlight has an inhibiting effect on the color development. No such inhibiting effect was noted in our laboratory, but subsequent investigation has shown that direct sunlight does cause relatively rapid fading, which may result in extremely low results if a fixed period is adhered to instead of making the reading at the time when maximum color has developed. It was, therefore, deemed advisable to investigate more thoroughly the effect of sunlight on the ortho-tolidin reaction.

The equipment used and the procedure followed in making the chlorine determinations are described in detail in a previous article.[1] The samples of chlorine water employed were prepared from a good grade of distilled water. Some of the experiments were carried out on the roof of a building under the direct rays of a July sun. Others were made in direct sunlight in a laboratory facing the morning sun. The controls were run in the diffused light of the laboratory and also in complete absence of light.

It was first noted that direct sunlight did not inhibit the formation of the color. Instead it accelerated it tremendously. A large number of determinations were made in diffused daylight and it was found that the maximum color resulted between one and two minutes after addition of

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the reagent. In direct sunlight, maximum color formation was reached in a few seconds, and when immediate comparison was made with the color standards, results were secured that checked very well with results obtained in diffused daylight. However, in direct sunlight fading was rapid, and it can be seen that if a fixed period of time is adhered to between the addition of the ortho-tolidin reagent and the reading, extremely erroneous values may result when tests are made in direct sunlight, as previously pointed out by Howard and Thompson[2].

The following table contains data that show the time rate of fading in strong sunlight, in weak sunlight and in diffused daylight. The first seven determinations were carried out on the roof of a large building under the direct rays of a midday July sun. Determinations number 8 to 12, inclusive, were made in the laboratory exposed to a rather weak morning sun. The last two determinations were made in diffused daylight. In addition, the samples of chlorine water were all analyzed previous to beginning the series, under conditions which would prevent any appreciable light effect. In all cases the controls checked the initial readings, as given in the table.

TABLE 1.

EFFECT OF SUNLIGHT ON CHLORINE DETERMINATIONS.

Elapsed Time (Minutes).	Chlorine Concentration (p.p.m.).													
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
0.5	0.6	0.6	0.5	0.5	0.6	0.6	1.0	0.6	0.6	0.75	0.75	1.0	0.65	0.75
5	0.4	0.4	0.4	0.4	0.2	0.4	0.45	0.5	0.5	0.70	0.70	0.75	0.65	0.75
10	0.4	0.35	0.1	0.25	0.1	0.4	0.2	0.4	0.45	0.55	0.65	0.7	0.65	0.75
15	0.1	0.25	0.0	0.2	0.05	0.3	0.1	0.35	0.45	...	...	0.7	0.65	...
20	0.0	0.2	0.0	0.15	0.0	0.2	0.0	0.25	0.45	0.4	0.6	0.65	0.65	0.75
25	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.2	0.40	0.3	0.6	0.55	0.60	0.75
30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	...	0.2	0.5	...	...	0.75

It is probable that the color-producing material in the ortho-tolidin method is similar to that class of partially-oxidized amines designated by Willstätter and Piccard[3] as meriquinones. It was previously reported by one of us[1] that when ortho-tolidin was treated with one equivalent of chlorine in glacial acetic acid, a crystalline product was isolated that gave in aqueous solutions, color changes that were similar to those secured by means of the ortho-tolidin reagent. The variations in color with pH were identical.

Solutions of this so-called meriquinone, when exposed to direct sunlight, faded just as did the test portions in the chlorine determinations. There was no indication that this fading was due to a reversible reaction, since addition of ortho-tolidin reagent showed that no free chlorine was present. In addition, the extremely large excess of ortho-tolidin hydrochloride present, when free chlorine is determined by the procedure em-

ployed, would preclude any such explanation. Apparently the color-giving compound is decomposed to yield products that give no color in the concentrations present.

Howard and Thompson[2] carried out some experiments in which they sought to prove that low results in direct sunlight were due to interference of color production, rather than to increased rate of chlorine absorption. As we have shown, it is not a matter of interference with color production, but a fading of the color that gives low results. Of course, for all practical purposes the mechanism is immaterial if one observes the color at the end of a fixed time, instead of at the point of maximum color formation, as should be done.

Howard and Thompson exposed samples of chlorinated water to direct sunlight for five minutes and found only a slight lowering in concentration. While this demonstrated that the low results they were securing were due only in small part to destruction of chlorine by sunlight, it should not be taken as evidence that exposure to direct sunlight may not cause a considerable lowering in the concentration of chlorine. Care should always be taken that samples of chlorinated water are protected from light. This may be of considerable importance when samples are transported to a laboratory for testing. In such cases the use of brown glass bottles is advisable.

The effect of sunlight on chlorinated water was shown by a series of tests in which samples were exposed to direct sunlight in 100-cc. glass-stoppered, clear glass bottles, the chlorine concentration being determined at different time intervals. Control samples were kept in brown glass bottles. The concentration fell off considerably in the clear glass bottles, but not at all in the controls.

TABLE 2.

EFFECT OF SUNLIGHT ON CHLORINATED WATER.

Type of Glass.	CONCENTRATION OF CHLORINE IN P.P.M. AFTER STATED NUMBER OF MINUTES.		
	0	20	30
Clear	0.5	0.2	0.1
Brown	0.5	0.5	0.5
Clear	0.9	0.4	0.1
Brown	0.9	0.9	0.9

Another series of tests was made in which bottles of chlorinated water were kept under ordinary laboratory conditions in diffused daylight. Samples in clear glass underwent some change, but controls in brown glass bottles did not. The size of bottle did not appear to have any effect.

TABLE 3.

EFFECT OF DIFFUSED DAYLIGHT ON CHLORINATED WATER.

Amount of Sample (cc.).	Type of Glass.	CONCENTRATION OF CHLORINE IN P.P.M. AFTER STATED NUMBER OF MINUTES.				
		0	15	30	45	60
1 000	Clear	0.6	0.5	0.45	0.4	0.4
500	Clear	0.6	0.5	0.45	0.4	0.4
100	Clear	0.6	0.5	0.45	0.4	0.4
500	Brown	0.6	0.6	0.60	0.6	0.6

Conclusions. 1. We are in agreement with Howard and Thompson that exposure to direct sunlight will cause low results in the determination of chlorine by the ortho-tolidin method, if a five-minute period is taken as standard.

2. Direct sunlight does not interfere with color formation, but leads to low results by causing the color to fade.

3. Satisfactory determinations can be made even in direct sunlight, if the point of maximum color formation is observed.

4. Unless it is absolutely necessary, chlorine determinations should be made in diffused light, but the maximum color should always be read, instead of observing a fixed time interval. This is extremely important when testing sewage and trade wastes.

5. Samples of chlorinated water undergo appreciable reduction in chlorine concentration when exposed to sunlight in clear glass bottles. Brown glass bottles should always be used in transporting samples.

REFERENCES.

[1]McCrumb, JOUR. N. E. W. W. ASSN. xli, 386, 1927.
[2]Howard and Thompson, Can. Engr. Oct. 19, 1926.
[3]Willstätter and Piccard, Ber. 41, 1458, 1908.

THE RAINFALL OF NEW ENGLAND.

PART IV. MINIMUM AND MAXIMUM MONTHLY RAINFALL OF SOUTHERN NEW ENGLAND.*

BY J. HENRY WEBER.†

ABSOLUTE MAXIMUM MONTHLY RAINFALL.

In January (Fig. 1) the maximum has exceeded 6 in. in all portions of the area, with the exception of a small one in the Connecticut Valley in northern Massachusetts. Most of Connecticut, southeastern Massachusetts and Rhode Island have experienced over 9 in., while some portions have had over 10 in. The highest reported at any station is 11.9 in., at Acushnet, Mass.

The maximum in February (Fig. 2) has exceeded 6 in. throughout the entire area. The 8- and 10-in. isohyets are numerous and show very little geographical arrangement, while in January they had been confined almost entirely to the southern portion. Although no station has reported a rainfall in excess of 12 in. (New London, 11.98 in.), it is interesting to note that most of Rhode Island and eastern Connecticut have experienced from 7 to over 8 in. in one storm, namely that of February 11–14, 1886.

In March (Fig. 3) there is less variation throughout the area than in the preceding months. The prevailing amount for the region is in the neighborhood of 8 in. The southern portion has recorded a slightly higher rainfall than the northern, a few stations there having values slightly over 10 in.

April (Fig. 4) is the first month to report a maximum exceeding 12 in. Such values are found in the interior of Connecticut and Rhode Island. For the remainder of the region, the prevailing values are in the vicinity of 8 to 10 in. Williamstown is the only station not to have recorded 6 in. of rainfall in April.

In May (Fig. 5) the absolute maximum values for southern New England are lower than any other month of the year. The prevailing values are in the vicinity of 7 to 8 in., while the extremes are 5.8 in. at Williamstown and 10.5 in. at Provincetown. Bridgeport is the only other station to have had more than 10 in.

June (Fig. 6) shows a higher and more varied maximum than in any of the preceding months. In the northern and western portions of the region the prevailing values are between 10 and 14 in., and in the southern and eastern, from 8 to 10 in. The major portion of the stations on the

*Editor's Note: This is the last of a series of four papers by J. Henry Weber on "The Rainfall of New England." "The Rainfall of Northern New England" by Gragg Richards follows.

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southern coast have maximum values under 8 in., Block Island, with 12.9 in. being the only notable exception. The highest values are 14.3 and 14.1 in. at Southampton and North Dana, Mass., respectively.

In July (Fig. 7) the variation of the maximum rainfall is extreme. The highest maximum, 19.90 in. at Southington, Conn., and the lowest maximum, 5.05 in. at Nantucket, are the greatest and least maxima for any month; this, in itself, is a remarkable contrast.

In the Connecticut River lowland and to the westward in Connecticut, the values are decidedly in excess of those of any preceding or following month, a number of stations in the southern part of Connecticut reporting values in excess of 18 in. From Southington to New London, Conn., a distance of 45 miles, the maximum varies from 19.9 in. to 7.1 in. The greater portion of this abnormally high rainfall fell in three storms, in July, 1897. Following is an excerpt from the New England Section of the Climate and Crop Service of the Weather Bureau, July, 1897:

The history of the regular and voluntary observation service in New England furnishes no parallel to the precipitation record of July, 1897. The extremes in the total fall for the month were 2.02 in. at Orono, Me., and 19.90 in. at Southington, Conn., a most remarkable variance considering the comparatively small area of the district.

Three great storms, namely, those of the 13th and 14th, 22nd and 29th produced the bulk of the abnormal large totals in the interior of New England (the coast sections averaged about normal). The first storm will probably stand as a memorable and distinctive one in Connecticut and western Massachusetts. The downpour lasted from thirty to thirty-six hours, and at the close of the storm it was found that from five to over ten inches had fallen in many sections, exceeding all records for any single storm, Southington, Conn., had 10.30 in. (in 33 hours); Bridgeport, Conn., 9.39; Windsor and Hartford, Conn., 9.22 and 9.17 in. respectively, while at the mouth of the Connecticut River the measurements were normal. Farther north through western Massachusetts and into Vermont, New Hampshire and Maine the amounts reached five and six inches, but along the eastern coast the precipitation was very small.

The second heaviest storm of the month came on the 22nd. This had remarkable local irregularities in Connecticut, where the precipitation was the greatest. In some localities the storm resembled a cloudburst and the consequent floods were worse than for many years. Finally on the 29th, the third deluge occurred, accompanied by severe electrical disturbances. These storms created flood conditions in various regions, which assumed altogether colossal proportions. Several lives were lost and the damage done amounted to thousands and thousands of dollars.

On the 16th, the Connecticut River at Hartford, Conn., was nearly twenty feet above low water mark while on the 30th it was but slightly lower. These are said to have been the first real floods in this river in July since 1683, according to Professor Hart of Trinity College.

In August (Fig. 8) the maximum is much less varied than in July, and the isohyets show very little geographical arrangement. The highest is 13.1 in. at Colrain, Mass.

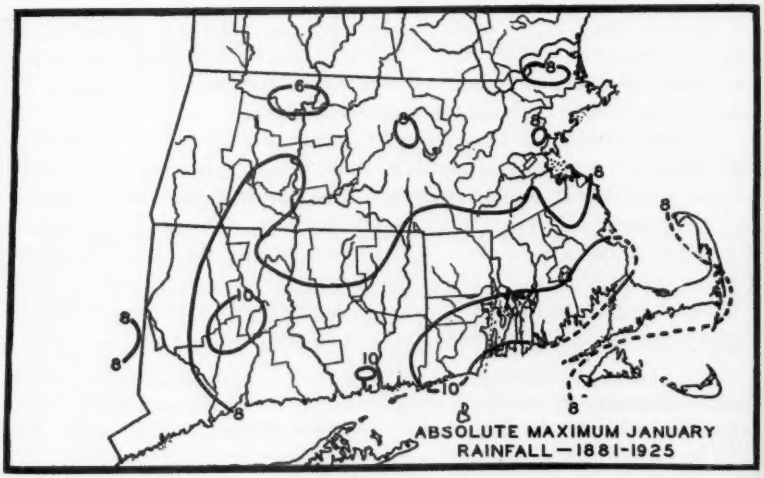

ABSOLUTE MAXIMUM JANUARY
RAINFALL — 1881-1925

FIG. 1.

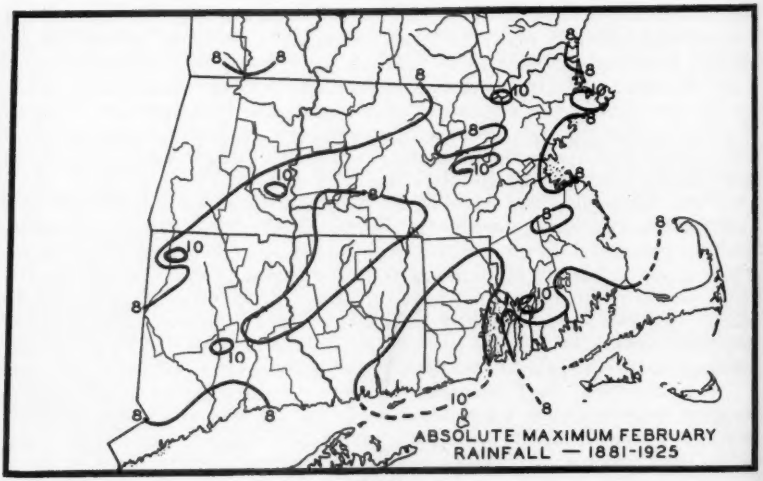

ABSOLUTE MAXIMUM FEBRUARY
RAINFALL — 1881-1925

FIG. 2.

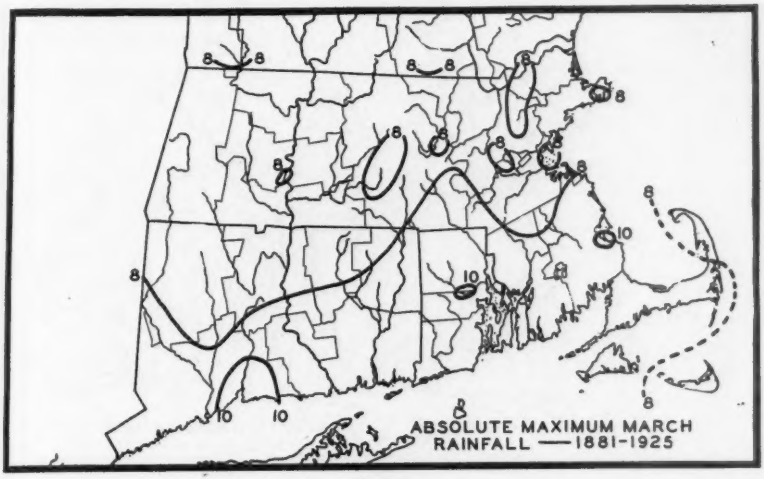

ABSOLUTE MAXIMUM MARCH
RAINFALL —1881-1925

FIG. 3.

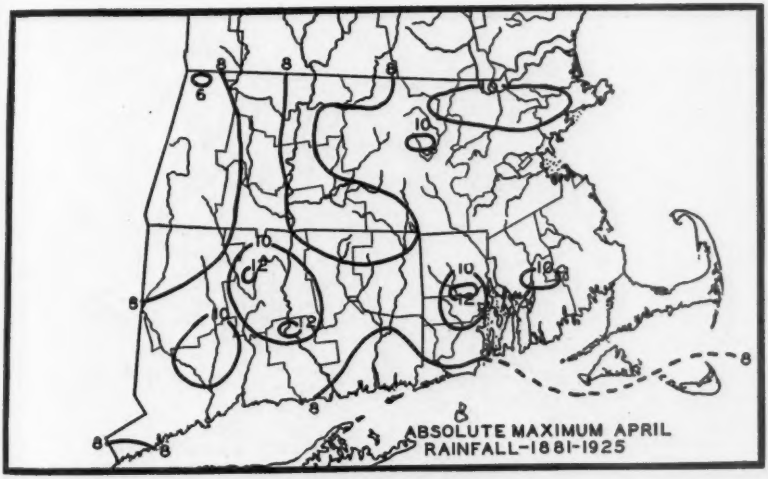

ABSOLUTE MAXIMUM APRIL
RAINFALL-1881-1925

FIG. 4.

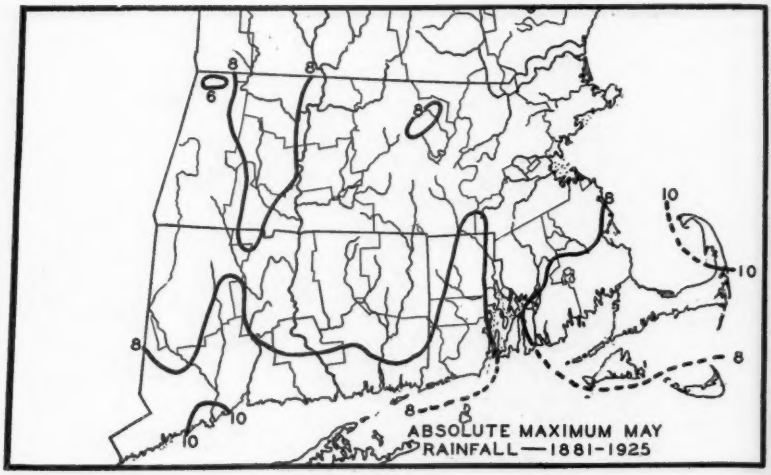

ABSOLUTE MAXIMUM MAY
RAINFALL—1881-1925

FIG. 5.

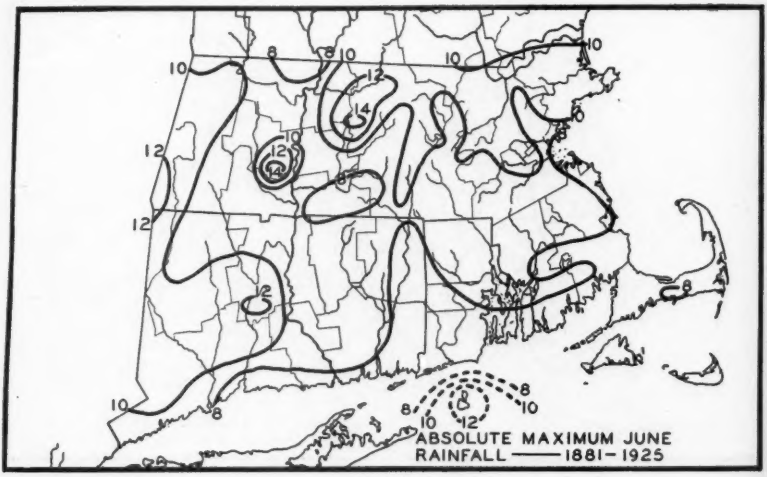

ABSOLUTE MAXIMUM JUNE
RAINFALL——1881-1925

FIG. 6.

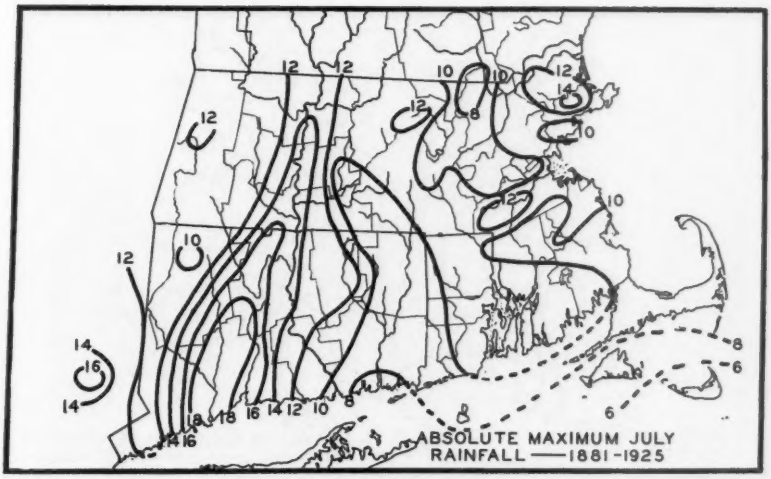

ABSOLUTE MAXIMUM JULY
RAINFALL —— 1881-1925

FIG. 7.

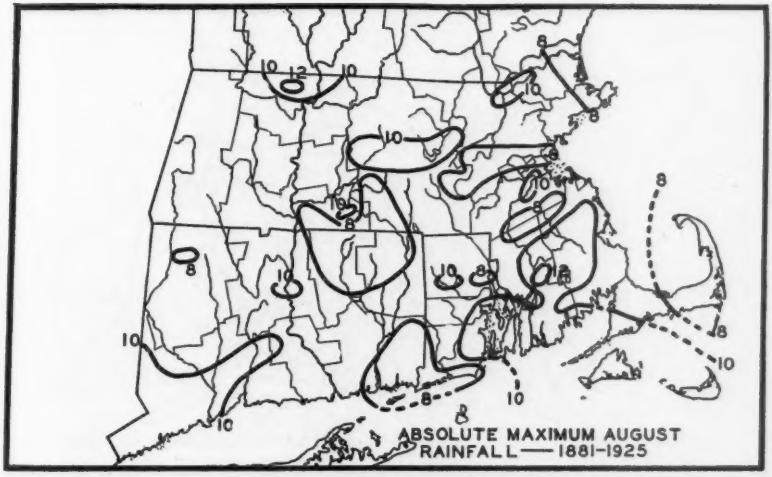

ABSOLUTE MAXIMUM AUGUST
RAINFALL —— 1881-1925

FIG. 8.

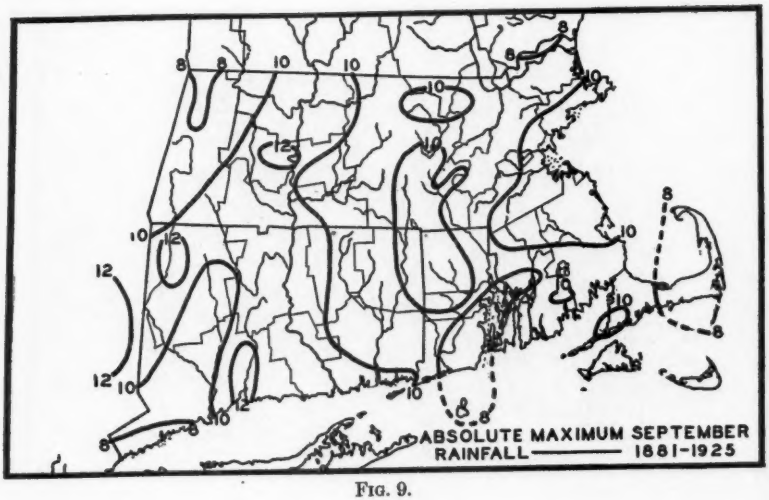

ABSOLUTE MAXIMUM SEPTEMBER
RAINFALL——— 1881-1925

FIG. 9.

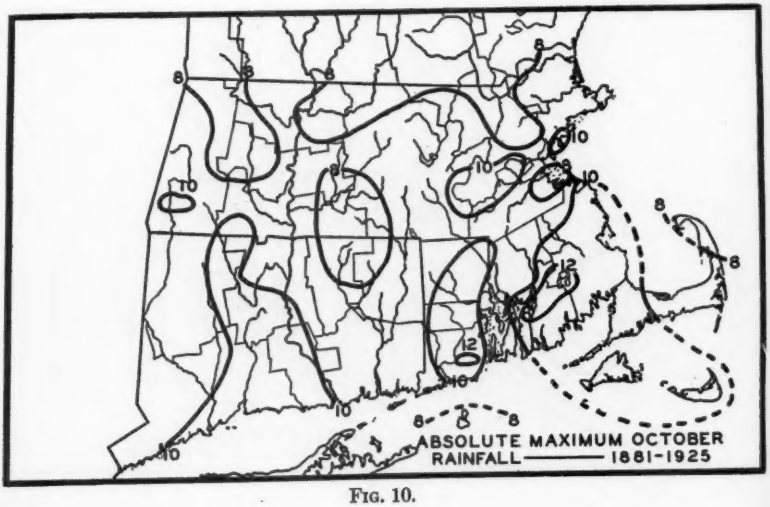

ABSOLUTE MAXIMUM OCTOBER
RAINFALL——— 1881-1925

FIG. 10.

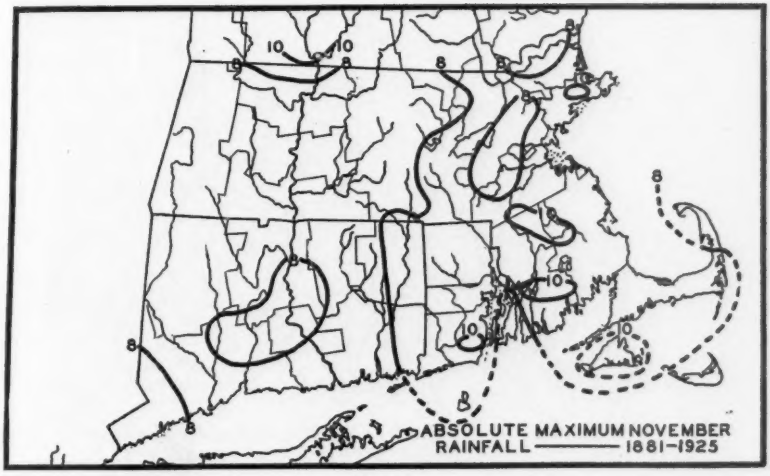

ABSOLUTE MAXIMUM NOVEMBER
RAINFALL ——— 1881-1925

FIG. 11.

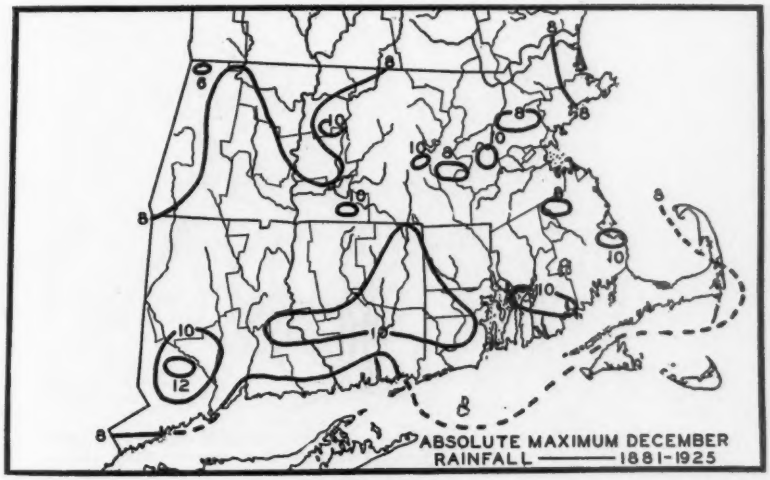
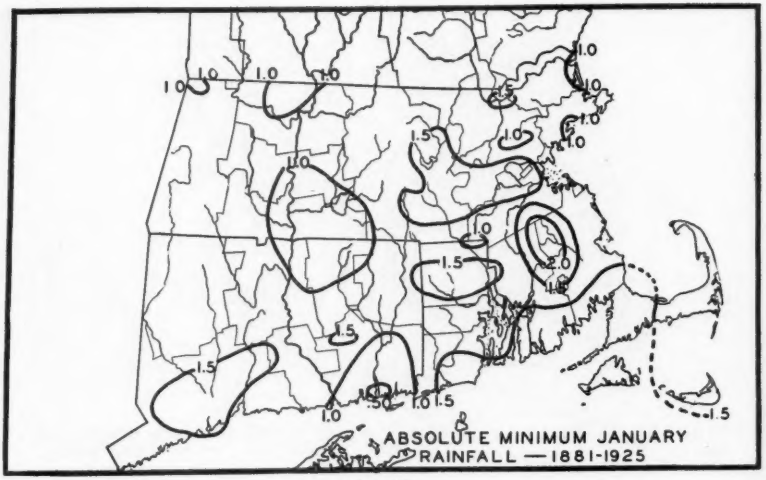

ABSOLUTE MAXIMUM DECEMBER
RAINFALL ——— 1881-1925

FIG. 12.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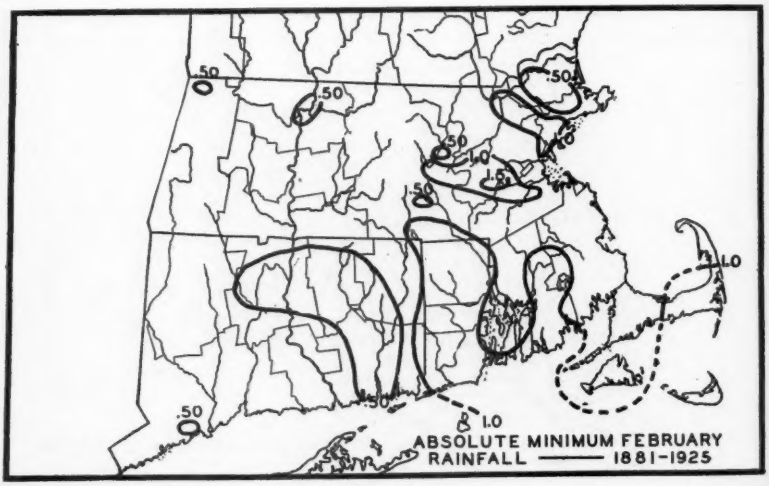
ABSOLUTE MINIMUM JANUARY
RAINFALL — 1881-1925

FIG. 13.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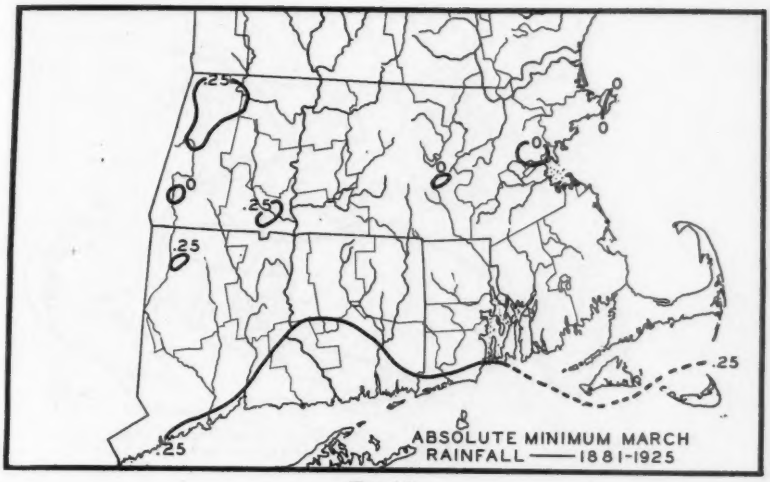
ABSOLUTE MINIMUM FEBRUARY
RAINFALL ——— 1881-1925

FIG. 14.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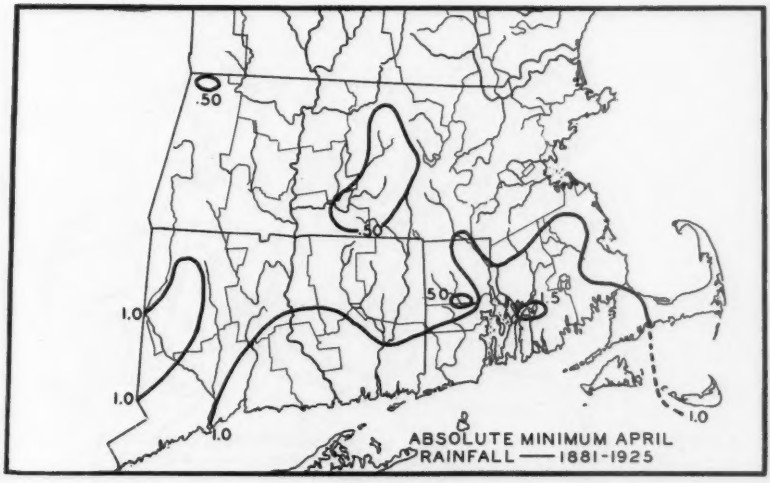
ABSOLUTE MINIMUM MARCH
RAINFALL —— 1881-1925

FIG. 15.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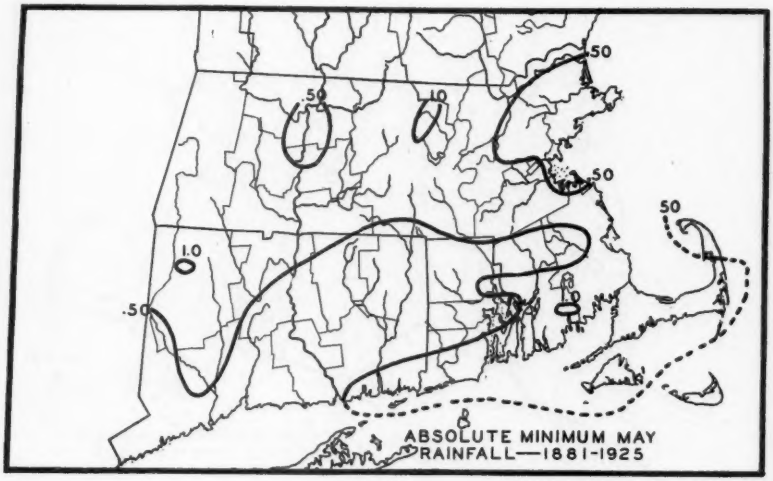
ABSOLUTE MINIMUM APRIL
RAINFALL —— 1881-1925

FIG. 16.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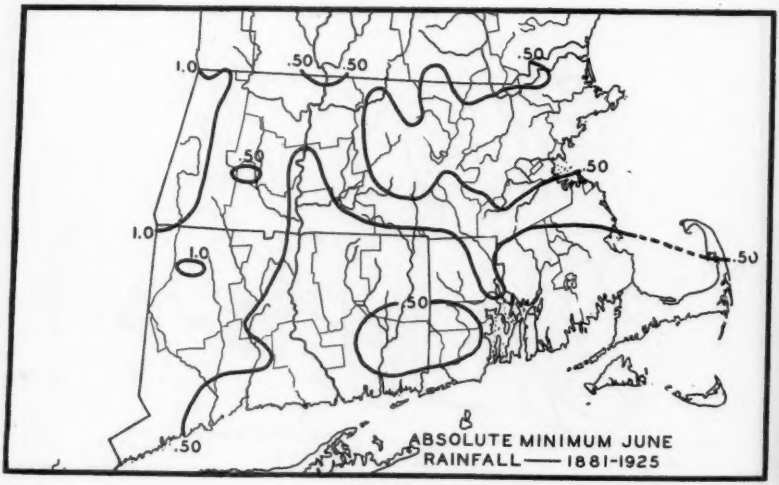
ABSOLUTE MINIMUM MAY
RAINFALL—1881-1925

FIG. 17.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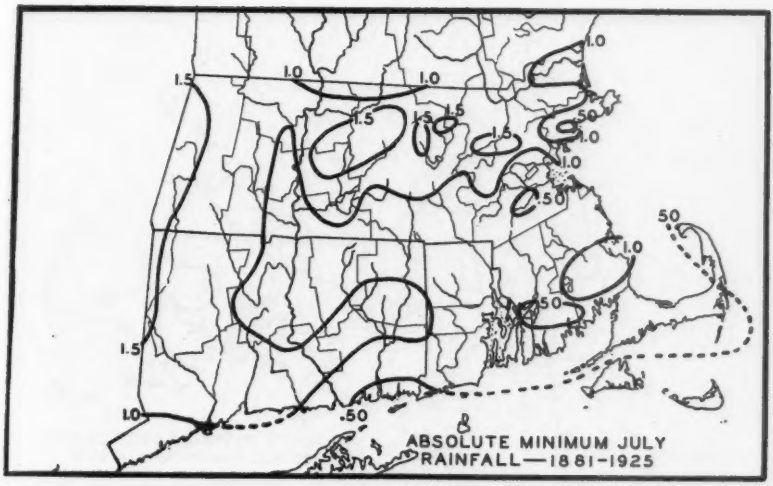
ABSOLUTE MINIMUM JUNE
RAINFALL—1881-1925

FIG. 18.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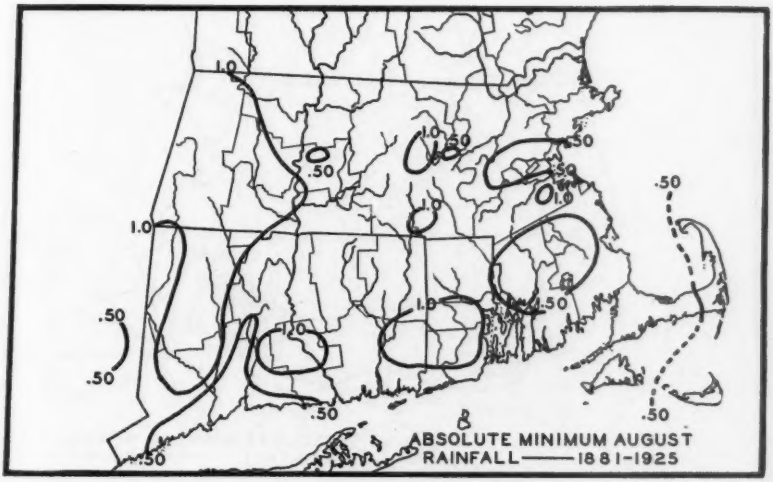
ABSOLUTE MINIMUM JULY
RAINFALL—1881-1925

FIG. 19.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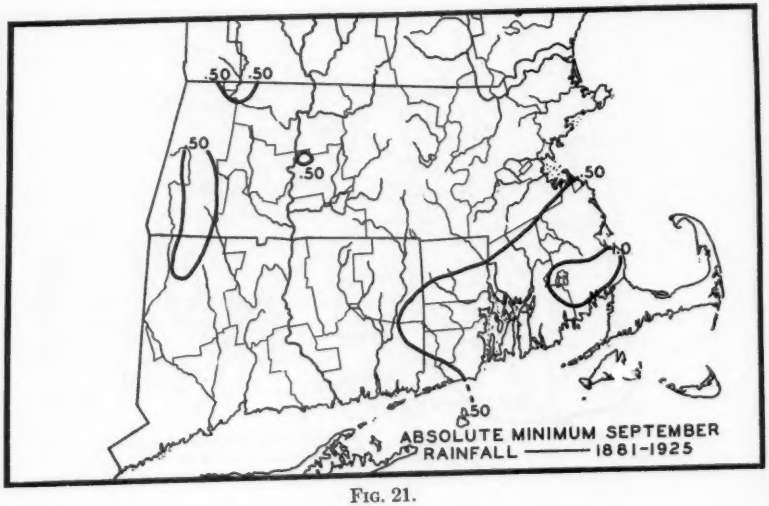
ABSOLUTE MINIMUM AUGUST
RAINFALL——1881-1925

FIG. 20.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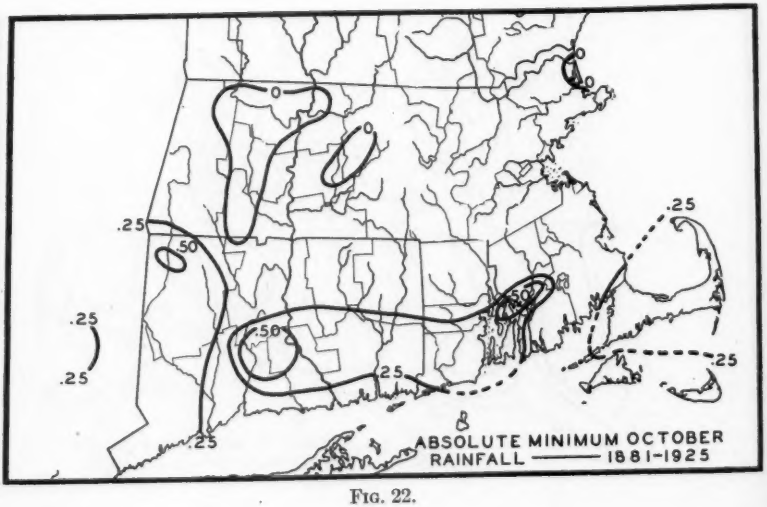
ABSOLUTE MINIMUM SEPTEMBER
RAINFALL ——— 1881-1925

FIG. 21.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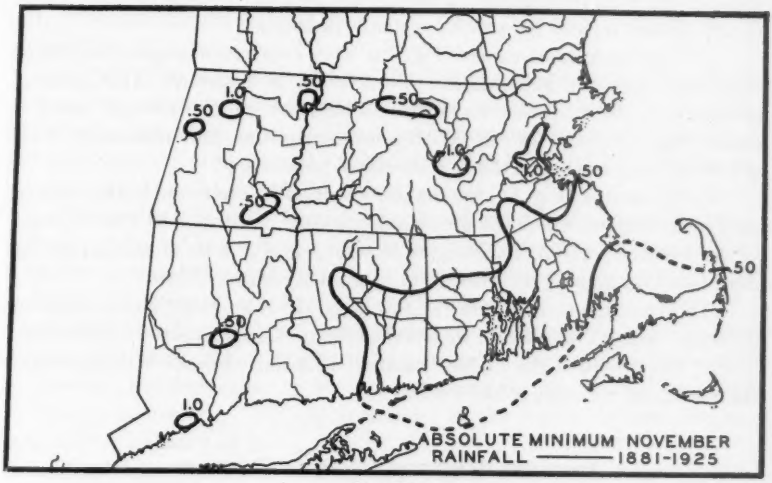
ABSOLUTE MINIMUM OCTOBER
RAINFALL ——— 1881-1925

FIG. 22.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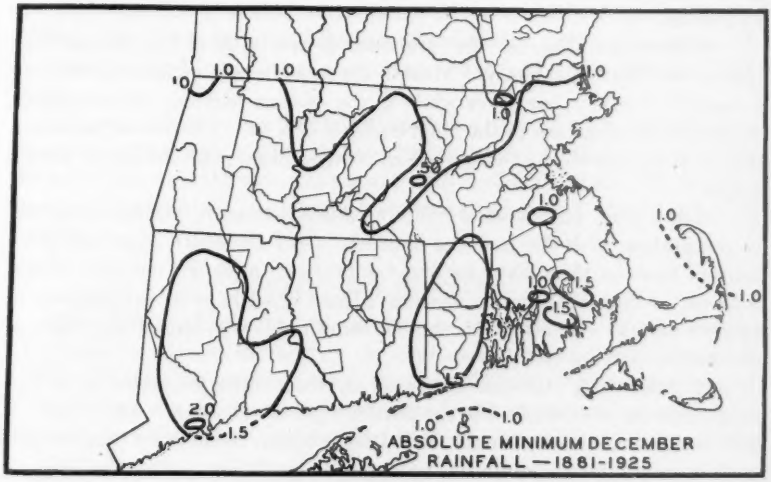
ABSOLUTE MINIMUM NOVEMBER
RAINFALL ——— 1881-1925

FIG. 23.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ABSOLUTE MINIMUM DECEMBER
RAINFALL — 1881-1925

FIG. 24.

The maximum September rainfall (Fig. 9) occurs in the Connecticut valley and to the westward. Here the values are in the neighborhood of 10 to 12 in., with the highest for the month, 13.1 in., at New Haven. Most of the coastal regions have values from 8 to 10 in.

October maximum values (Fig. 10) have a variation similar to that of September but the geographical distribution is different. The greatest rainfall is in the southeastern portion, inland, where the amounts in a few cases, slightly exceed 12 in. With a few exceptions, amounts under 8 in. are found only in the northern and central portions.

In November (Fig. 11) the maximum amounts are found in the eastern part of the region, where the prevailing amounts are from 8 to 10 in. Most of the western portion of the region has not received 8 in. of rainfall in this month. The highest recorded is 11.5 in. at Acushnet, Mass.

The December maximum rainfall (Fig. 12) is greatest in the southern portion, inland, and least in northwestern Massachusetts. Newtown, Conn., has recorded the highest rainfall, 12.3 in., while at Williamstown, the maximum amount is but 5.9 in.

Absolute Minimum Monthly Rainfall.

In January (Fig. 13) no very low minimum rainfalls have been recorded, New London, Conn., being the only station to have had as low as 0.50 in. For the region as a whole, the amounts have not fallen below 1.0 to 1.5 in., while at Taunton, Mass., the lowest recorded in January is up to 2.05 in.

In February (Fig. 14) the minimum at nearly all of the stations has fallen lower than in January. Most of the western portion has experienced a rainfall of 0.50 in. or lower while in the eastern portion, the prevailing minimum amounts are in the neighborhood of 1 in. The lowest recorded is 0.13 in. at Norwich, Conn., while at Natick, Mass., the amount is above 1.5 in.

March (Fig. 15) shows a profound difference in the minimum rainfall in comparison with the previous months. Only the south coast and portions of western Massachusetts and Connecticut, have not recorded under 0.25 in. Many stations in eastern Massachusetts have experienced a rainless month. March, 1915, was the month of lowest rainfall throughout the greater portion of the area.

In April (Fig. 16) the minimum in the southern portion is in the neighborhood of 1.0 in. and in the northern portion, 0.50 in. The lowest is 0.25 in. at Templeton, Mass. Fall River, Mass., is the only long-record station where the minimum has not fallen below 1.5 in.

Nearly all of the area has recorded below 1 in. of rainfall in May (Fig. 17), while a large portion has received under 0.50 in. The lowest amounts are along the western coast of Connecticut with Greenwich reporting the lowest, .01 in.

Nearly all the region east of the Connecticut River has had under 0.50 in. in June (Fig. 18), while many stations report values under 0.25 in. The lowest is 0.09 in. at Haverhill, Mass. For the extreme western portion of Massachusetts and at Cream Hill, Conn., the minimum amount is above 1 in.

In July (Fig. 19) there are considerable local variations, although in general, the southern portion has the lowest amounts; here the amounts have fallen, in general, below 0.50 in. In the northern and western portions the minimum amounts are in the neighborhood of 1.0 to 1.5 in. The lowest recorded is 0.22 in. at Nantucket, Mass.

Throughout the area, August (Fig. 20) shows a lower minimum rainfall than July. The western portions have not experienced below 1 in. while in the remainder of the region the values, in general, are between 0.50 to 1.0 in. The lowest is 0.10 in. at Provincetown.

September (Fig. 21) has a lower minimum rainfall throughout the area than in any preceding month excepting March. Only the southeastern portion and small areas in the western part have always received over 0.50 in. during September. For the remainder of the region the amounts are generally less than 0.25 in.

The October minimum rainfall map (Fig. 22) is next to March in low values. Outside of the southern portion and western Connecticut, the amounts are well below 0.25 in. Many stations in Massachusetts, particularly in the western portion, have had a rainless month. The low rainfall occurred throughout the area in October, 1924.

In November (Fig. 23) most of the southeastern portion has had under 0.50 in. For the remainder of the area the minimum values are, in general, between 0.50 and 1 in. The lowest recorded is 0.13 in. at Turners Falls, Mass.

There are no very low minimum values in December (Fig. 24), Holden, Mass., being the only station to have had an amount below 0.50 in. For the rest of the area the amounts are generally well above 1 in. Bridgeport, Conn., is the only station always to have had at least 2 in. of rainfall in December.

Summary and Conclusion.

The data available furnish satisfactory mean annual rainfall values, with their variations, for most of the southern portion of New England, while more stations are desirable in northern Maine, New Hampshire and Vermont and also in the central portion of the last-named state. It is believed, however, that the essential rainfall features have been shown within these areas.

The seasonal distributions are such that the coastal regions have their greatest mean monthly rainfall in the winter months and the least in the summer, while the far interior has an opposite distribution. Between these two regions, the monthly rainfall distribution is practically uniform.

In southern New England, the mean monthly and seasonal values appear to be of a satisfactory degree of accuracy except in the higher elevations in central and western Massachusetts and portions of western Connecticut. The three types of rainfall distribution noted for the New England region as a whole, are distinctly shown here, most particularly the coastal and the near interior types.

Maximum and minimum values are naturally less satisfactory and are subject to more change with increasing length of record. The period used is sufficiently long to show that any part of southern New England may receive over 10 in. and under 0.25 in. in some months. Maximum values are greatest in the northern and western portions in the summer months, while in winter the maximum values are usually found in the southern portion. The minimum values are not as low during the winter as they are in other seasons. March and October are the only months when rainless conditions have been experienced over even a portion of the area.

THE RAINFALL OF NORTHERN NEW ENGLAND.*

BY GRAGG RICHARDS.†

MEAN SEASONAL RAINFALL.‡

The spring rainfall (Fig. 1) for the greater part of this region ranges from 8 to 11 in Near the stormier coast it generally amounts to more than 10 in., while falling under 9 in. in northern New Hampshire and Vermont, and in that part of Maine over 100 miles inland. Aside from Mt. Washington, the only high-altitude station, with 18.03 in., Bar Harbor, Me., (12.61 in.) alone receives over 12 in. Areas receiving less than 8 in. are confined to the Lake Champlain region, the upper Connecticut Valley, and northern Maine. West Stewartstown, N. H., (5.8 in.) a valley station behind mountains, shows the lowest rainfall.

In summer the rainfall (Fig. 2), as a whole, is somewhat heavier, mostly between 10 and 12 in. But in contrast to spring conditions, central Maine and both northern and southern New Hampshire and Vermont, now warm and convectively active, receive over 12 in., while stations near the chilly coast, except Bar Harbor (10.2 in.) record slightly under 10 in. Mt. Washington has 28.04 in.; other stations receiving over 14 in. are Woodstock, N. H., Victory and Readsboro, Vt. The only station under 8 in. is Houlton, Me. (7.7 in.).

The general distribution of rainfall for autumn (Fig. 3) resembles that for spring. Parts of the Maine coast receive over 12 in. as compared with 8 to 10 in. for the interior. For New Hampshire and Vermont, the relative precipitation is similar to that for both spring and summer, individual stations showing, in general, less rain than in summer, but more than in spring. Besides Mt. Washington (22.49 in.), the only stations recording over 13 in. are Woodland, Me., (13.1 in.) and Somerset, Vt.,(13.4 in.). Kineo, Me., (7.4 in.) and Fitzdale (7.7 in.) and Ryegate, Vt., (7.9 in.) are the low-record stations, all in rain-shadow locations.

Precipitation along the coast is heavier in winter (Fig. 4) than in either spring or autumn, while becoming the lowest of any season for the interior. Greater storminess on the coast and the lower temperatures of the interior are responsible. Mt. Washington (13.65 in.) no longer stands out in contrast to the coastal stations of Bar Harbor, Belfast and Calais, Me., and Somerset, Vt., (all 13.6 in.). The upper Connecticut Valley, Fitzdale, and Guildhall, Vt., (5.1 in.) and the Lake Champlain region — Burlington, Vt., (5.15 in.) — persist as lowland areas of light precipitation in the rain shadows of the neighboring highlands.

*Project of the Clark University Graduate School of Geography, under the supervision of Charles F. Brooks.

†Mining Geologist, Detroit, Michigan.

‡Reference should be made to the general account of the seasonal rainfall of New England, with diagrams and map, in this JOURNAL, September, 1928, pp. 278–283.

MEAN SPRING RAINFALL
1881-1925

FIG. 1.

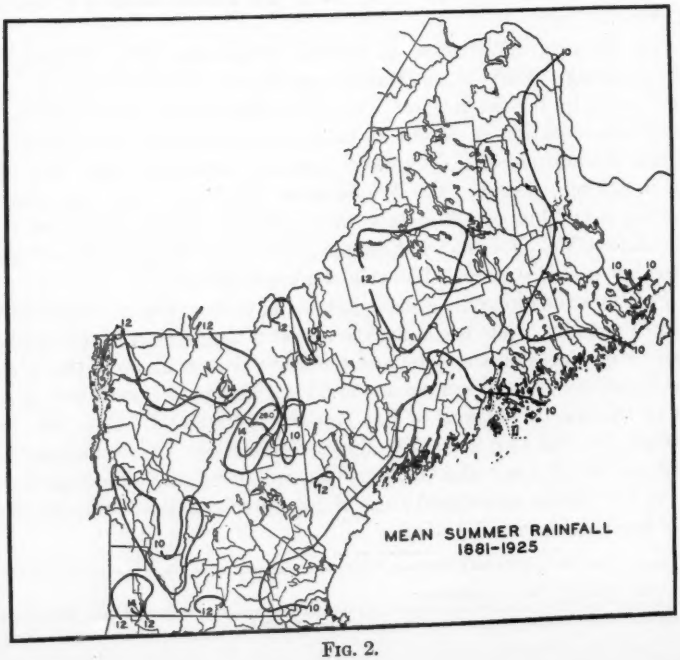
MEAN SUMMER RAINFALL
1881-1925

FIG. 2.

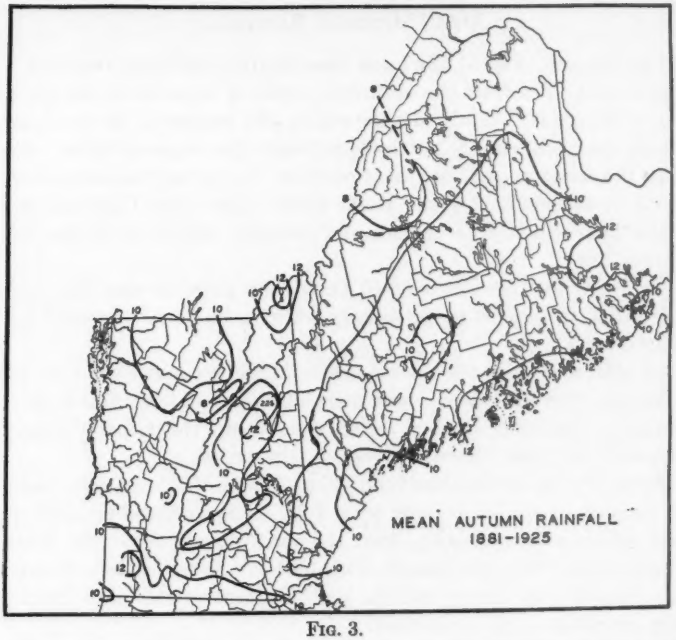
MEAN AUTUMN RAINFALL
1881-1925

FIG. 3.

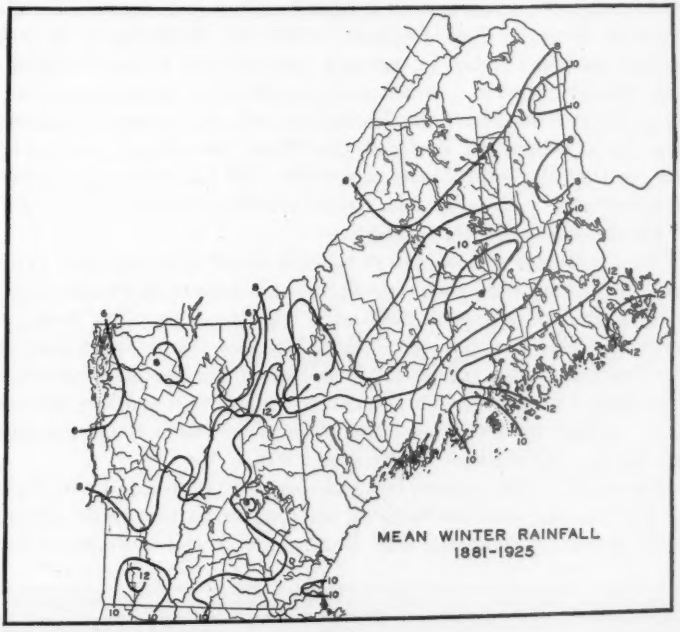
MEAN WINTER RAINFALL
1881-1925

FIG. 4.

Mean Monthly Rainfall.*

For January (Fig. 5), the mean precipitation decreases from the coast inland so that a line from the southwest corner of Vermont to the northeast corner of Maine roughly divides the region into two areas, the southeastern receiving over 3 in. and the northwestern with lighter precipitation. Except for Mt. Washington (4.27 in.) and Somerset, Vt.,(4.8 in.) stations recording over 4.5 in. are confined to the Maine coast. The upper Connecticut Valley, the Lake Champlain region, and probably northern Maine, receive less than 2 in.

February distribution (Fig. 6) practically parallels that for January, precipitation in general being slightly lower as would be expected for the shorter month.

In March (Fig. 7), the coastal belt of Maine receives over 4 in., northern Maine, New Hampshire and most of Vermont, less than 3 in. Mt. Washington and Bar Harbor record over 5 in.; the upper Connecticut Valley and the Lake Champlain region, 2 in. or less.

April (Fig. 8) shows a marked falling off in rainfall, especially along the coast, where no station records over 4 in. The southeastern half of the region, still receives more than 3 in., the northwestern less. Mt. Washington now stands out prominently with 5.94 in. Northeastern Maine, the upper Connecticut Valley and the southern part of the Lake Champlain region are areas of lighter rainfall.

May (Fig. 9) is marked by a nearly uniform distribution of rainfall throughout northern New England. Only Mt. Washington (6.17 in.), the upper Deerfield Valley in southern Vermont and scattered stations in Maine register over 4 in. A belt with breaks, showing less than 3 in., extends northeastward from Lake Champlain, includes the upper Connecticut Valley, New Hampshire, north of the White Mountains, and northern Maine, so that the coastal belt, as a whole, still has heavier precipitation than the interior. Houlton, Me., and West Stewartstown, N. H., are the only stations showing 2 in. or under.

The prevalence of a rainfall of between 3 and 4 in. continues through June (Fig. 10), but the average precipitation is higher, and areas with over 4 in. now predominate over those with less than 3 in. The former now occur in northern Vermont, New Hampshire and Maine, while continuing in the Deerfield Valley and on Mt. Washington, but the latter have shifted to the lower Connecticut and Merrimac valleys and stations in eastern Maine. Except for Mt. Washington (9.08 in.), Readsboro has the highest mean, 4.9 in. All stations receive over 2.5 in.

The rainfall in the coastal belt remains at between 3 and 4 in. for July (Fig. 11), but increases markedly in the interior, so that much of northwestern Maine and northern New Hampshire, as well as Vermont, record

*Cf. Southern New England in this Journal, September, 1928, pp. 291–302. The same principles of seasonal distribution, particularly, more rainfall in winter than in summer on the coast, and more in summer than in winter in the interior, presented by Mr. Weber for southern New England, are seen to apply here.

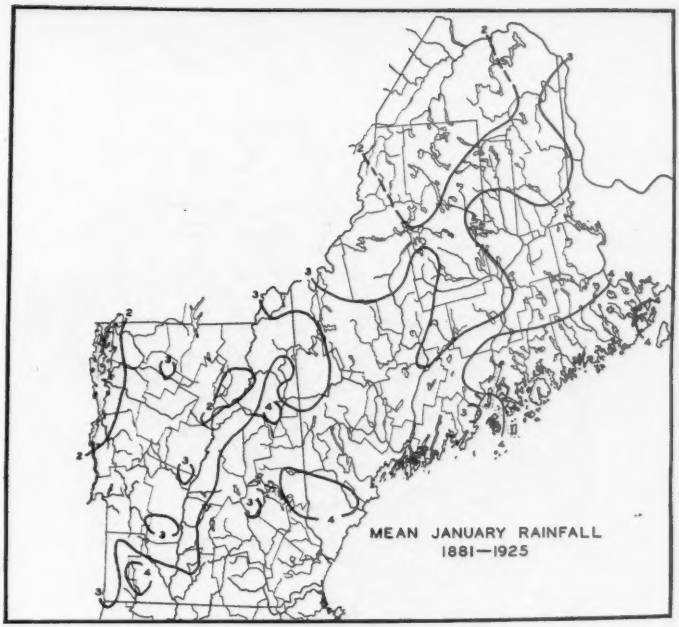
MEAN JANUARY RAINFALL
1881—1925

FIG. 5.

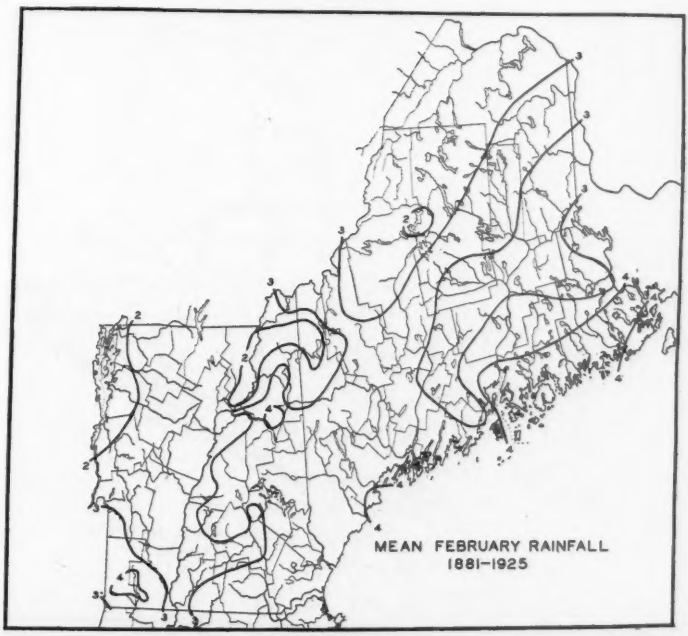
MEAN FEBRUARY RAINFALL
1881-1925

FIG. 6.

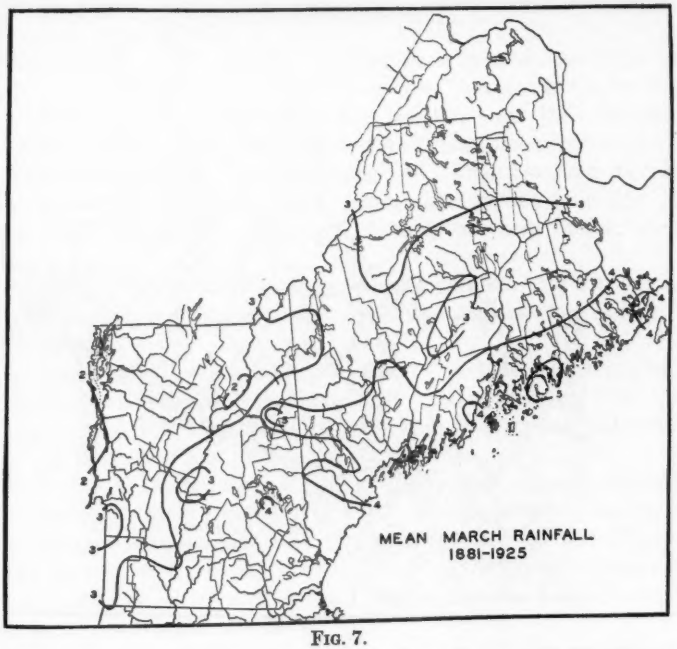
MEAN MARCH RAINFALL
1881-1925

FIG. 7.

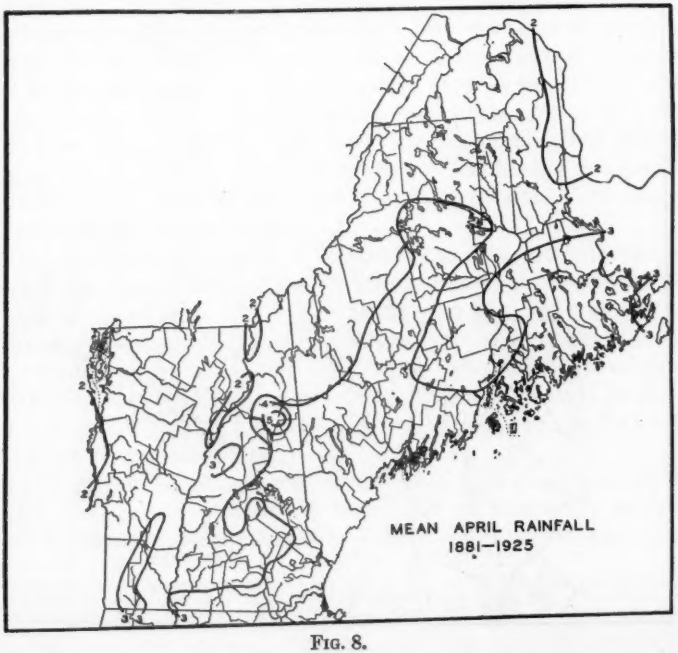
MEAN APRIL RAINFALL
1881—1925

FIG. 8.

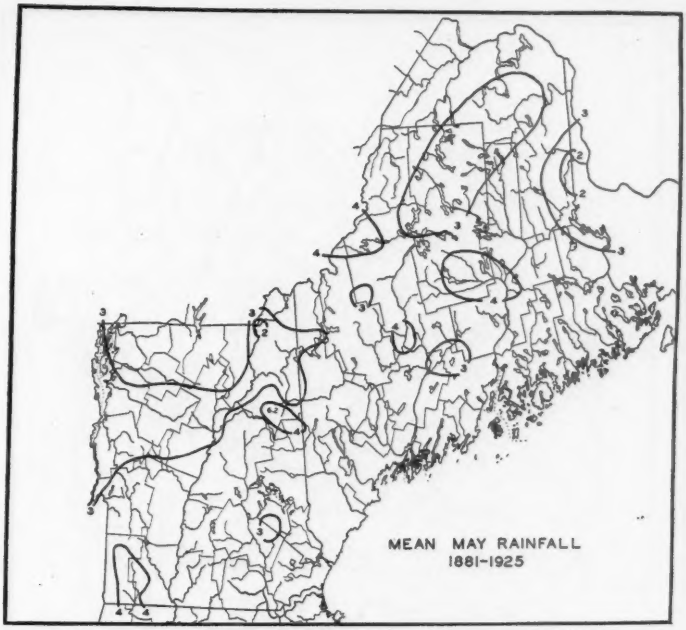

FIG. 9.

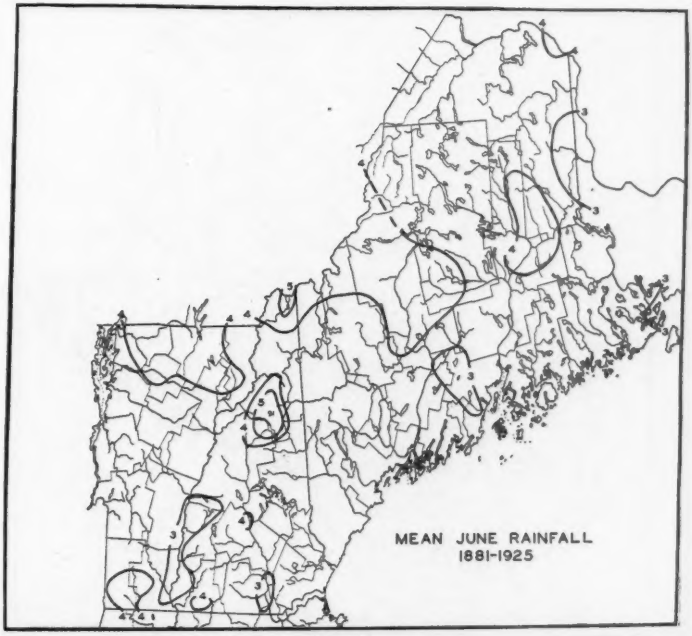

FIG. 10.

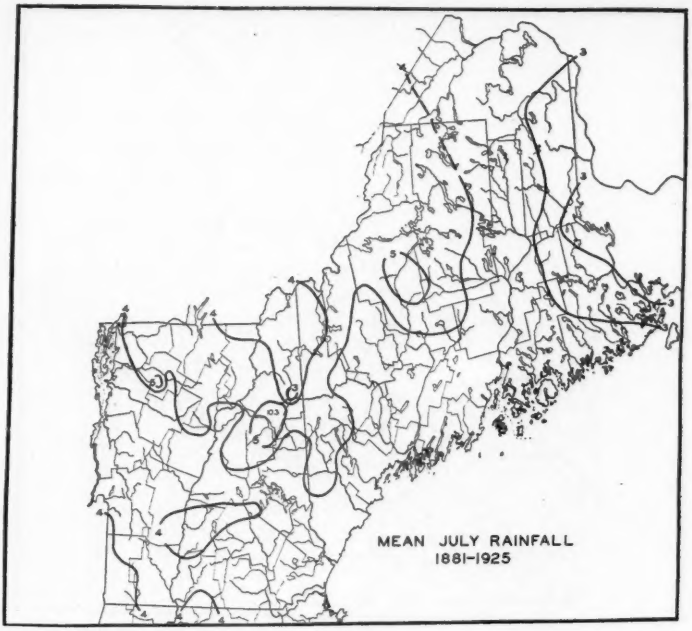
MEAN JULY RAINFALL
1881-1925

FIG. 11.

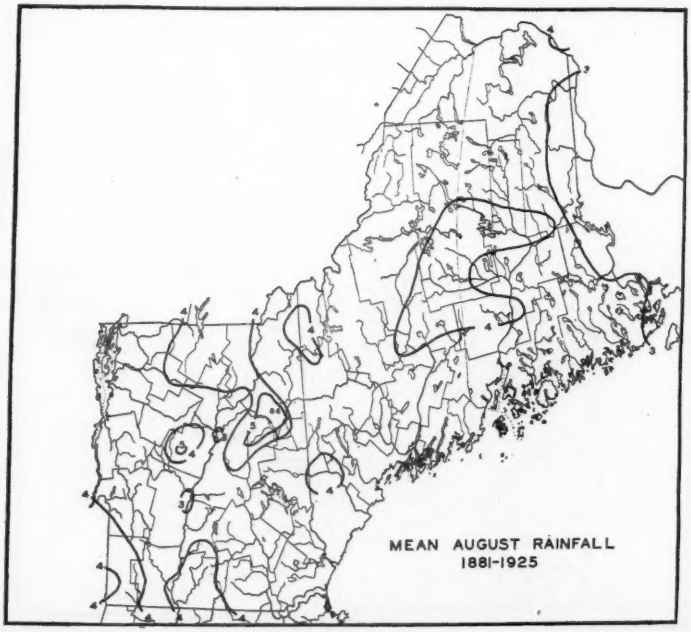
MEAN AUGUST RAINFALL
1881-1925

FIG. 12.

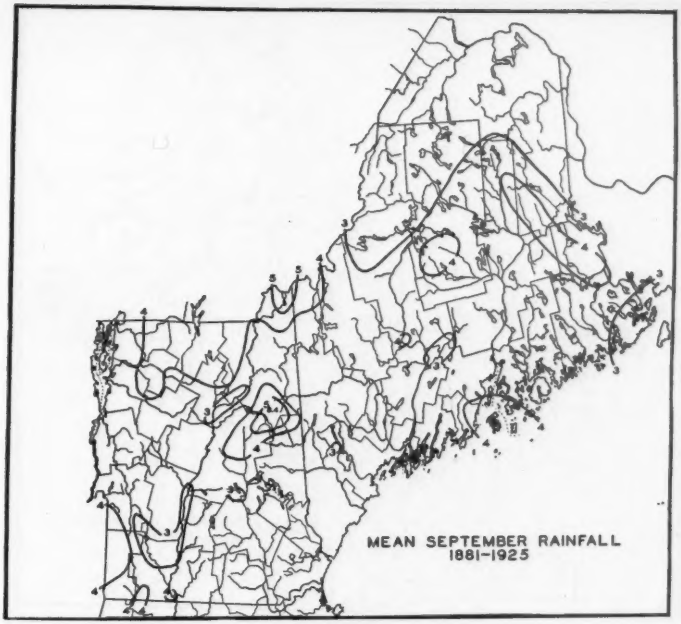
MEAN SEPTEMBER RAINFALL
1881–1925

FIG. 13.

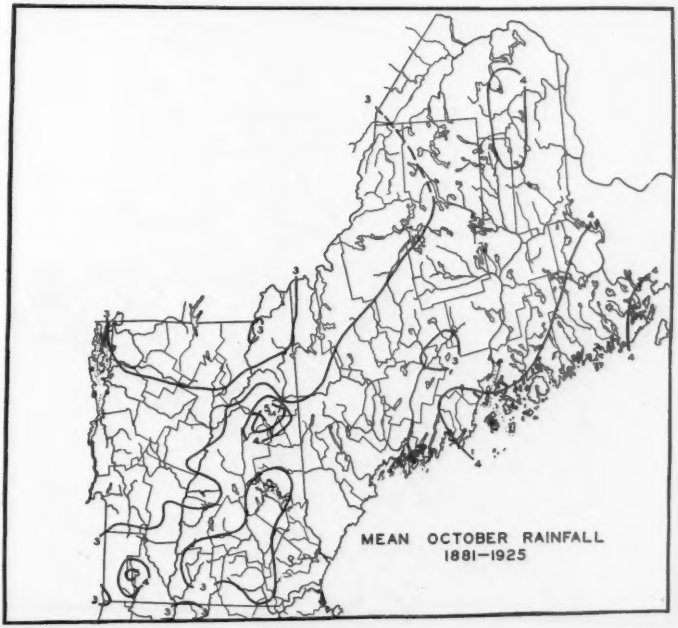
MEAN OCTOBER RAINFALL
1881–1925

FIG. 14.

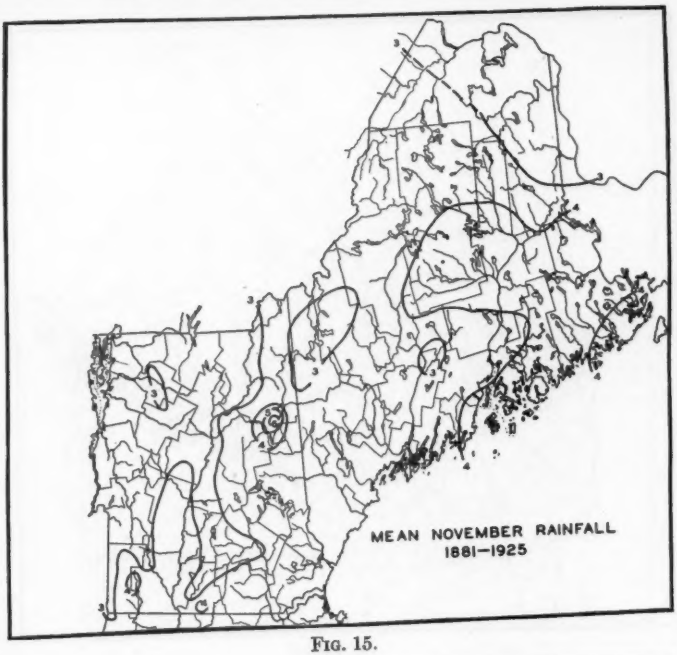
MEAN NOVEMBER RAINFALL
1881–1925

FIG. 15.

MEAN DECEMBER RAINFALL
1881–1925

FIG. 16.

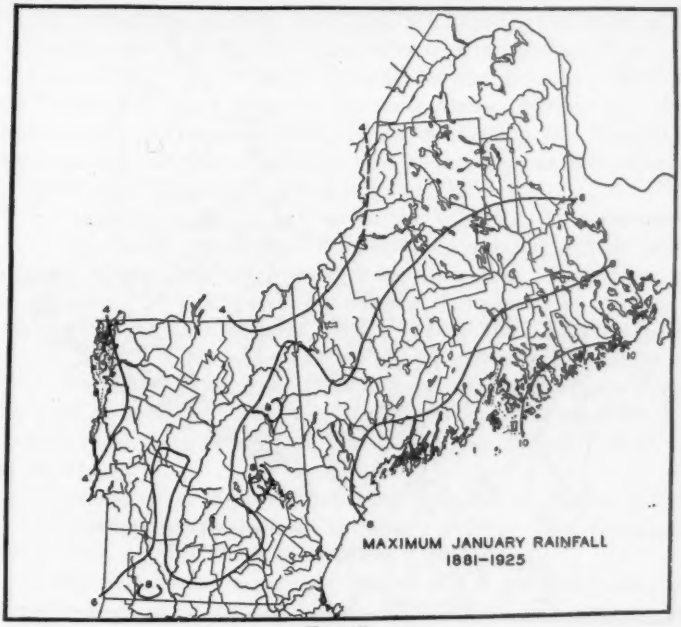
MAXIMUM JANUARY RAINFALL
1881–1925

FIG. 17.

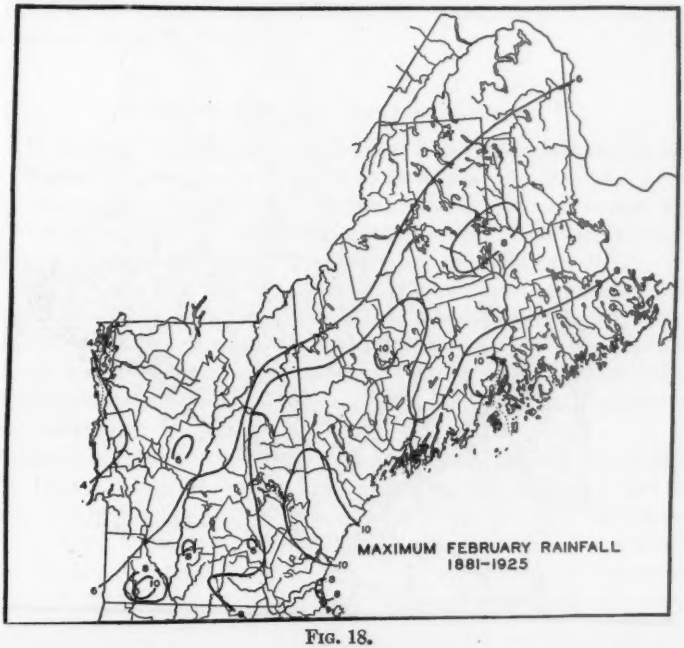
MAXIMUM FEBRUARY RAINFALL
1881–1925

FIG. 18.

MAXIMUM MARCH RAINFALL
1881-1925

FIG. 19.

MAXIMUM APRIL RAINFALL
1881-1925

FIG. 20.

over 4 in., several stations over 5 in., and Mt. Washington, 10.34 in. A strip along the eastern border of Maine, alone receives less than 3 in.

By August (Fig. 12), the heaviest rainfall for the region as a whole has passed. Areas with over 4 in. occupy the same general positions as in July, but have shrunk and means of over 5 in. are confined to Mt. Washington (8.62 in.) and its vicinity. Besides eastern Maine, stations in the Connecticut Valley again begin to show values under 3 in.

The rainfall is somewhat heavier on the coastal belt in September (Fig. 13), while much of northern Maine and an increasing number of stations in the Connecticut Valley, receive less than 3 in. Aside from Mt. Washington (8.42 in.), only scattered stations show over 4 in.

In October (Fig. 14), much of the Maine coast receives over 4 in. and the interior, except in the northwest, over 3 in. In New Hampshire and Vermont, precipitation is lighter than in September. The Lake Champlain region, most of the Connecticut Valley, and much of southern New Hampshire, receive less than 3 in. Mt. Washington records 7.45 in. and Somerset, Vt., 5.0 in.

In November (Fig. 15), conditions along the coast are similar to those for October, but many interior stations show a decrease. Mt. Washington (6.62 in.) is the only station with a mean of over 5 in.

The only considerable area receiving over 4 in. is confined to the coast of Maine in December (Fig. 16). Most of the interior has a lighter precipitation than 3 in., and Burlington, Vt., (1.85 in.) and stations in the upper Connecticut Valley fall under 2 in. Mt. Washington (5.22 in.) alone receives over 5 in.

Absolute Maximum Monthly Rainfall.*

The heaviest precipitation recorded for January at long-record stations in the region (Fig. 17) varies from 11.15 in. at Bar Harbor, Me., to 3.59 in. at Burlington, Vt. Roughly, stations within 100 miles of the coast have received over 6 in. in some one January, while those farther inland, have not. No station, except Bar Harbor, has recorded over 10 in.

For February (Fig. 18), the extremes in maximum precipitation occur in Vermont — 12.74 in. at Jacksonville and 3.86 in. at Cornwall, both in the same year, 1900. A line from the southwest corner of Vermont to the northeast corner of Maine serves rather accurately as a boundary, inland of which not over 6 in. of precipitation is to be expected. Few stations have received over 10 in.

Maximum records of less than 6 in., for March (Fig. 19), are confined to the Lake Champlain region, upper Connecticut Valley, and northern Maine. All of the Maine coast has received over 8 in., and Bar Harbor, 14.37 in. Over 9 in. has not been recorded in New Hampshire or Vermont, except on Mt. Washington (14.52 in.). The low-maximum long-record

*Cf. Southern New England in the preceding paper of this Journal.

MAXIMUM MAY RAINFALL
1881-1925

FIG. 21.

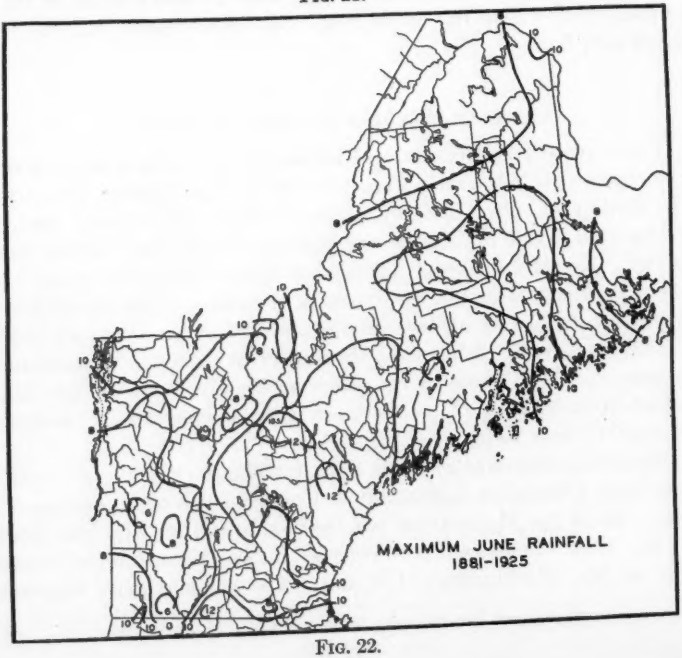
MAXIMUM JUNE RAINFALL
1881-1925

FIG. 22.

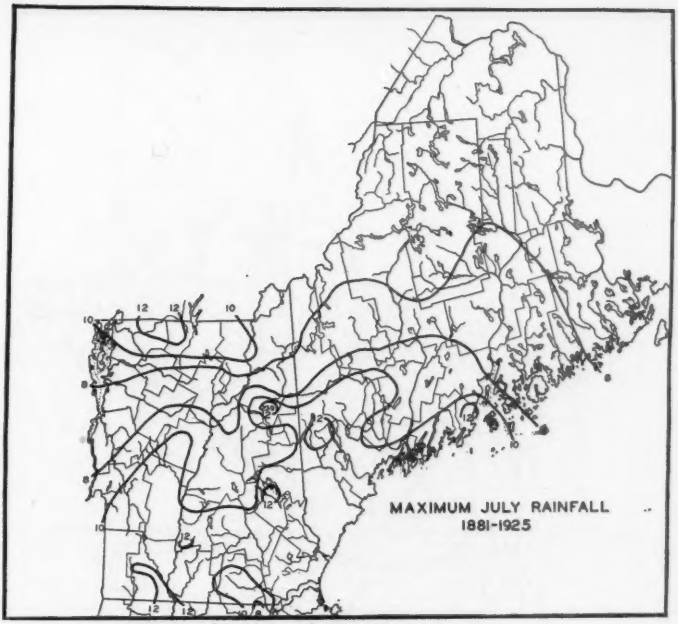
MAXIMUM JULY RAINFALL
1881-1925

FIG. 23.

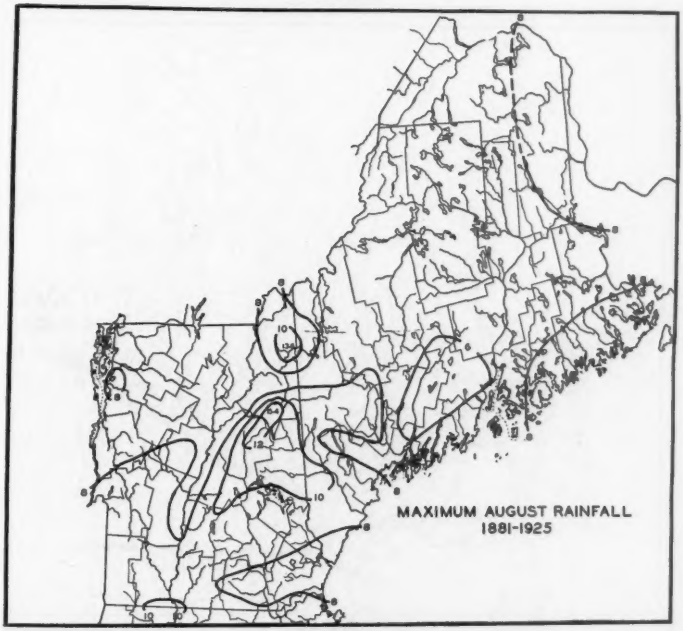
MAXIMUM AUGUST RAINFALL
1881-1925

FIG. 24.

MAXIMUM SEPTEMBER RAINFALL
1881-1925

FIG. 25.

MAXIMUM OCTOBER RAINFALL
1881—1925

FIG. 26.

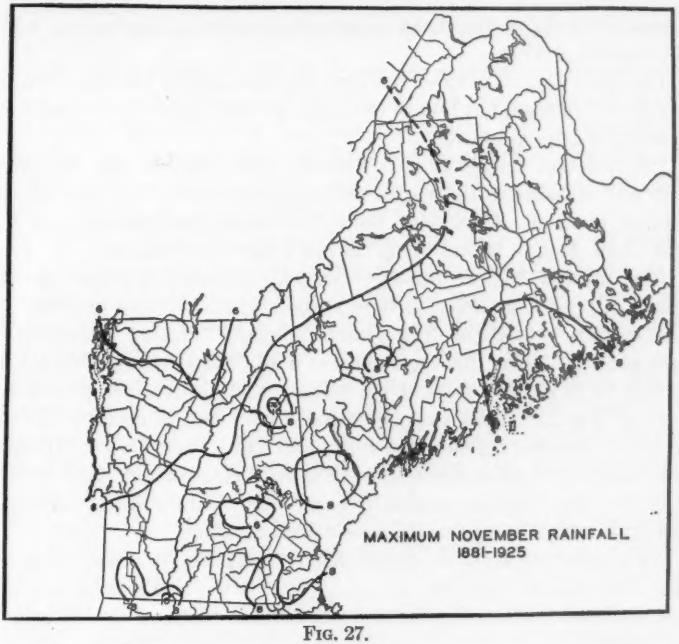
MAXIMUM NOVEMBER RAINFALL
1881-1925

FIG. 27.

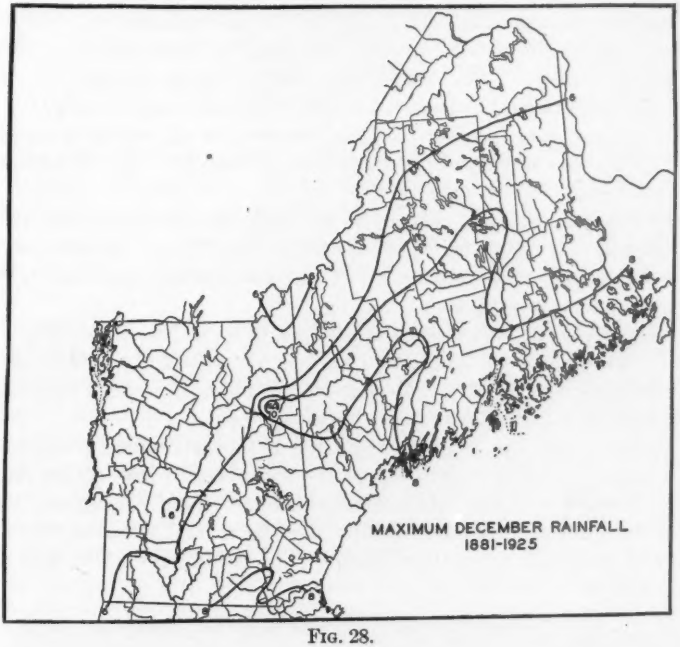
MAXIMUM DECEMBER RAINFALL
1881-1925

FIG. 28.

stations are both in the Lake Champlain region — Burlington, 4.53 in. and Cornwall, 4.55 in.

For April (Fig. 20), there has been little change in the 6-in. boundary of maximum rainfall, but falls of over 8 in. are confined to the coast, except for scattered interior stations.

Precipitation of over 10 in. is limited to Bar Harbor, Me., Mt. Washington and stations to the south, and to Jacksonville, Vt., Cornish, Me., recording 11.52 in. Practically the entire region has received over 5 in., Upper Dam, Me., (4.98 in.) being the low long-record station.

May rainfall (Fig. 21) has exceeded 6 in. in nearly all of northern New England, Upper Dam, Me., (5.49 in.) again being the low-maximum long-record station. Little of New Hampshire and Vermont, excepting Mt. Washington (12.50 in.), has received over 8 in. Eastport, Me., has the high record of 13.22 in., and most of the Maine coast has received over 8 in.

June (Fig. 22) shows a very irregular distribution of maxima, but most long-record stations register over 9 in., and many over 10 in. Mt. Washington comes into prominence with 18.46 in. Halifax and West Rutland, Vt., record their highest rainfall of under 6 in. in June, 1922, a month of maximum rainfall in much of northern New England.

All long-record stations, except Bar Harbor, Me., (6.55 in.) show maxima of over 7 in. in July (Fig. 23), many over 10 in., and several over 12 in. The maximum for Mt. Washington is 23.90 in., followed by Vernon, Vt., with 13.65 in.

August maxima (Fig. 24) of over 10 in. are confined practically to northern and central New Hampshire, including Mt. Washington (15.39 in.) and Errol (13.60 in.). An area in south central Maine, including Belfast, Fairfield, Winslow and Gardiner, has not received as much as 6 in.

Records of over 10 in. are well distributed over the region in September (Fig. 25), and all long-record stations show over 6 in. Mt. Washington (15.23 in.) alone records over 12 in.

In October (Fig. 26), but a few scattered stations show over 10 in. rainfall, and only Mt. Washington (18.38 in.) over 11 in. Eastern Maine is the only considerable area having received over 8 in. Hanover, N. H., has a maximum of but 5.49 in.

The only stations having recorded over 10 in. in November (Fig. 27), are Mt. Washington (17.55 in.) and Vernon, Vt., (10.12 in.). Most of the region has not received 8 in., but generally over 6 in., except for some Lake Champlain and upper Connecticut Valley stations.

In December (Fig. 28), some regularity in the distribution of maximum precipitation becomes evident again, the southeastern part of the region having received over 6 in., the northwestern less. Mt. Washington (15.95 in.), is the only station with a record of over 10 in., and an excess over 8 in. is limited practically to southern Maine. The maximum for Cornwall, Vt., is but 4.54 in.

Absolute Minimum Monthly Rainfall.*

Nearly all of northern New England has experienced Januarys with less than 1.0 in. of precipitation (Fig. 29), but few parts have not received at least 0.5 in. While most of the immediate coastal belt has not recorded less than 1.0 in., Portland, Me., (1.83 in.) is the only station with a minimum of over 1.5 in. Fairfield, Me., received but 0.31 in. in January, 1896, a month of minimum precipitation at many stations.

In February (Fig. 30), no station shows a minimum of as much as 1.5 in., and few, mostly near the Maine coast, in excess of 1.0 in. A belt from Lake Champlain to Durham, N. H., has received less than 0.5 in. Northfield, Vt., has a low record of 0.18 in., in February, 1901; that month and February, 1895, accounting for many of the minima.

Practically all of the region has had a March precipitation (Fig. 31) of under 0.5 in. March, 1915, was a month of light rainfall, Halifax, Vt., and Manchester, N. H., recording no precipitation, and neighboring stations, as well as Bar Harbor, Me., but a trace. Oldtown, Me., however, received 1.05 in. in the same month.

For April (Fig. 32), most stations record minima of between 0.5 and 1.0 in. Portland and Lewiston, Me., and Keene, N. H., have always received at least 1.0 in. during this month. No rain fell at Upper Dam, Me., in April, 1899, and but 0.07 in. on Mt. Washington in April, 1872.

Many stations show minima for May (Fig. 33) of less than 0.5 in. Manchester, N. H., (1.26 in.), is the only long-record station that has not received less than 1.0 in. No rain fell at Upper Dam, Me., and but a trace at Burlington, Vt., in May, 1903, a month of generally light rainfall. In other years, Errol, N. H., had a rainless May, and Bar Harbor, Me., but a trace.

For June (Fig. 34), most of the northwestern part of the region, has not received less than 1.0 in., though under 1.5 in., while parts of the Maine coast, as well as of southern New Hampshire and Vermont, have low records of less than 0.5 in. But 0.10 in. fell at Bar Harbor, Me., and at Concord, N. H., in June, 1913, a month of generally light rainfall, as was also June, 1912.

Manchester, N. H., (0.31 in.) is the only station with a minimum of under 0.5 in. in July (Fig. 35). The Maine coast, a strip across southern New Hampshire and Vermont, and Burlington on Lake Champlain have records of less than 1.0 in. For the rest of northern New England, minima at long-record stations vary from 1.0 to 1.5 in.

A large area in central Maine, has received under 0.5 in. in August (Fig. 36), but a trace falling at Orono in August, 1899. The rest of the region has low records of 0.5 to 1.0 in., except for Burlington, Vt., (1.05 in.) and some stations in central New Hampshire.

In September (Fig. 37), practically the whole region has received less

*Cf. Southern New England in the preceding paper of this Journal.

MINIMUM JANUARY RAINFALL
1881—1925

FIG. 29.

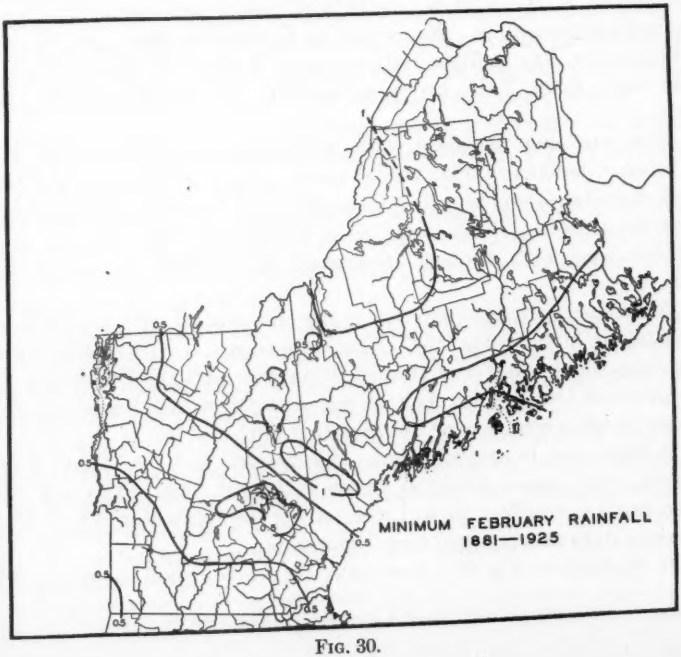
MINIMUM FEBRUARY RAINFALL
1881—1925

FIG. 30.

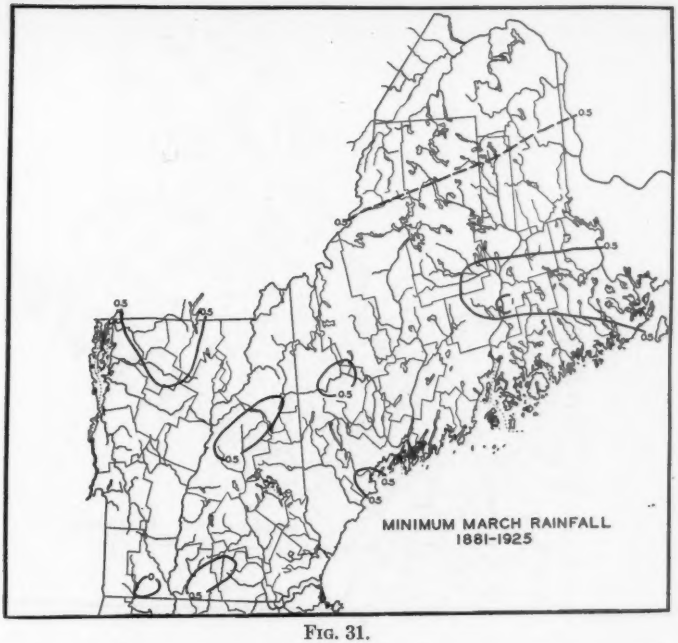
MINIMUM MARCH RAINFALL
1881-1925

FIG. 31.

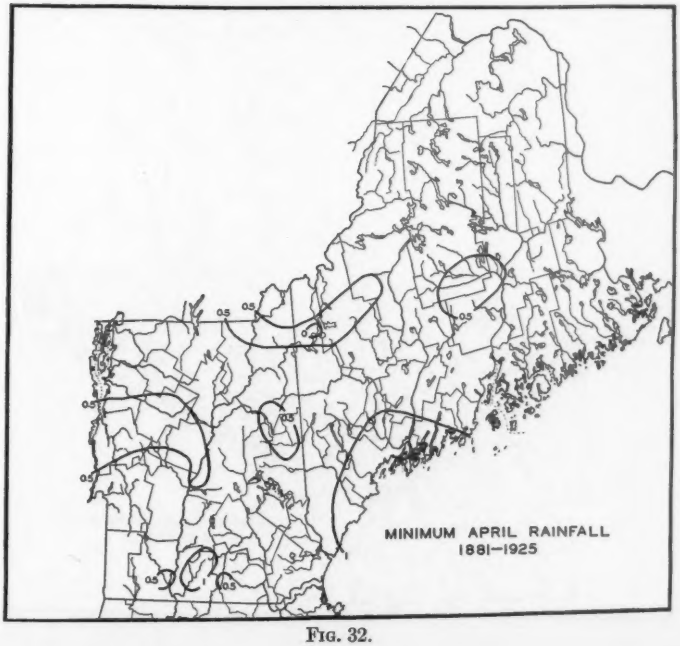
MINIMUM APRIL RAINFALL
1881-1925

FIG. 32.

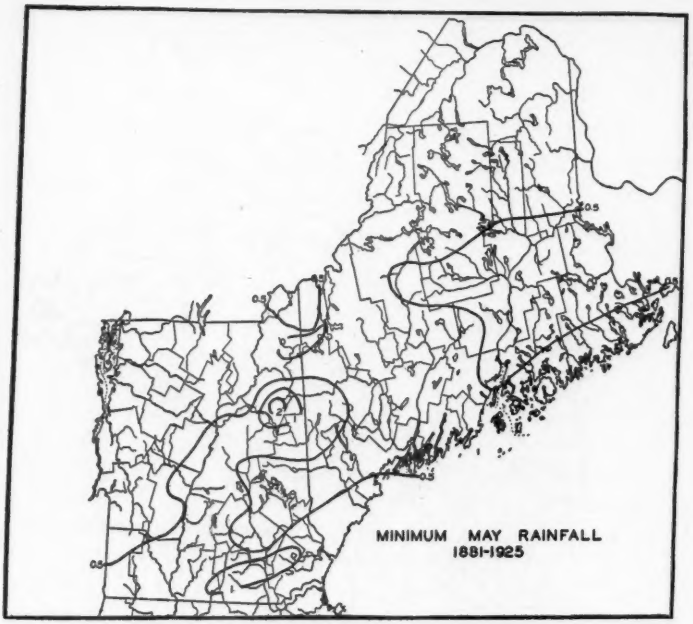
MINIMUM MAY RAINFALL
1881-1925

FIG. 33.

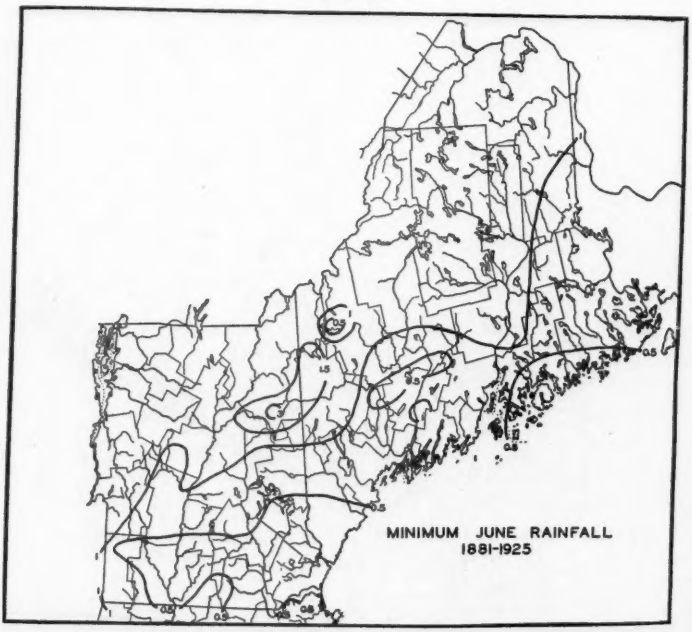
MINIMUM JUNE RAINFALL
1881-1925

FIG. 34.

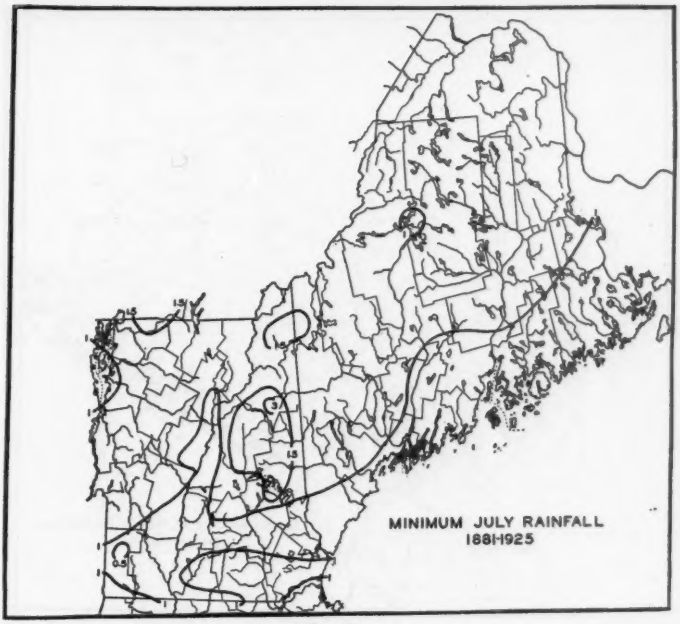
MINIMUM JULY RAINFALL
1881-1925

FIG. 35.

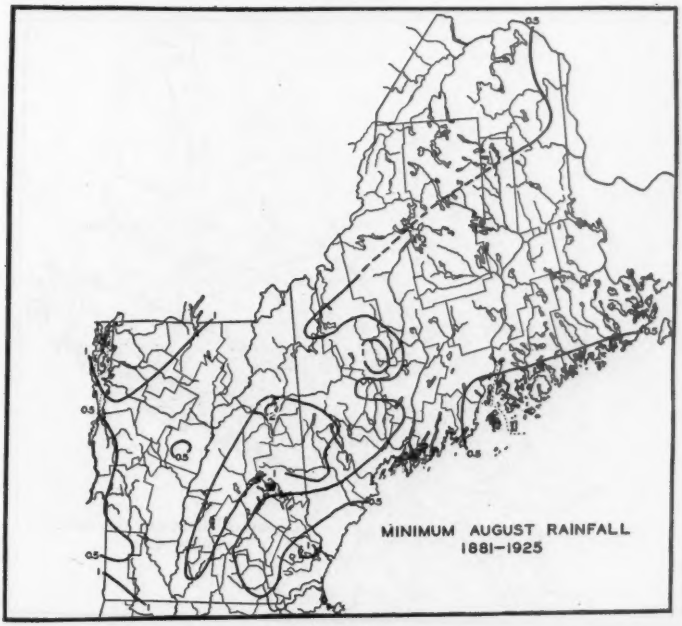
MINIMUM AUGUST RAINFALL
1881-1925

FIG. 36.

MINIMUM SEPTEMBER RAINFALL
1881—1925

FIG. 37.

MINIMUM OCTOBER RAINFALL
1881—1925

FIG. 38.

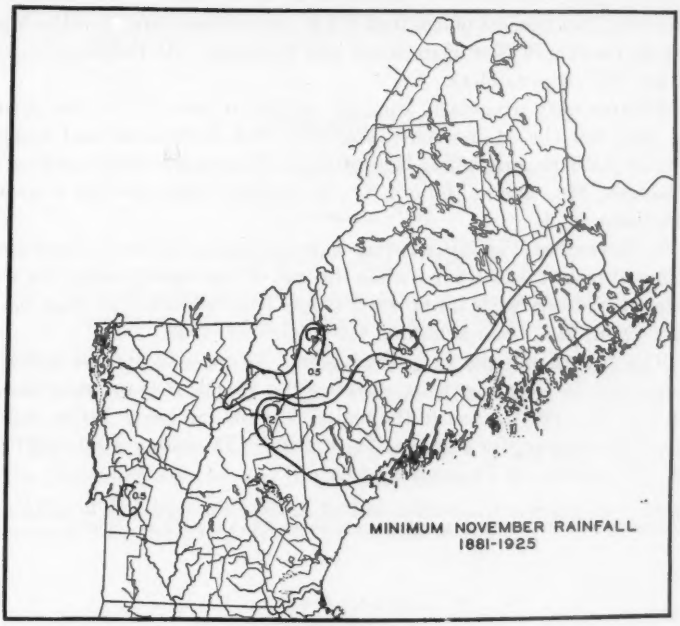
MINIMUM NOVEMBER RAINFALL
1881-1925

FIG. 39.

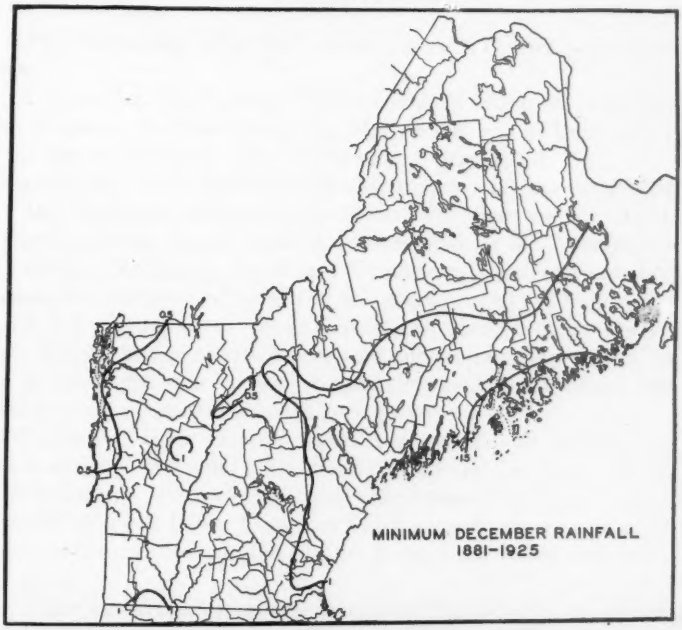
MINIMUM DECEMBER RAINFALL
1881-1925

FIG. 40.

than 1.0 in., but minima of less than 0.5 in. are confined largely to the Maine coast and southern New Hampshire and Vermont. At Patten, Me., September, 1917, was rainless.

Minima vary irregularly from no rainfall to over 1.5 in. for October (Fig. 38), but the Maine coast, southern New Hampshire and much of Vermont, have records falling below 0.5 in. No precipitation was recorded at Camden, Me., and at Halifax, Vt., in October, 1924, and but a trace at Fitzwilliam, N. H.

In November (Fig. 39), a rather wide belt along the Maine coast shows minima of from 1.0 to 1.5 in., while the rest of the region, except for a few scattered stations with lower values, has received not less than 0.5 in. Upper Dam, Me., records no rain for November, 1903.

The belt of minima between 1.0 and 1.5 in. still persists along the Maine coast in December (Fig. 40), but Bar Harbor has not recorded less than 1.95 in. For the rest of the region, minima fall below 1.0 in., but not under 0.5 in., except for Fitzdale, Vt., 0.24 in. in December, 1914, and Cornwall, Vt., 0.38 in., in December, 1892.

NOTE. The individual monthly and the mean seasonal and monthly rainfalls for all stations in New England for all years of record through 1928 will be published in a later issue of the JOURNAL.

PROCEEDINGS.

Forty-seventh Annual Convention.

Montreal, P. Q.

September 18–21, 1928.

The following is a synopsis of such parts of the proceedings at the Montreal convention as appears to be of value for the record.

The Forty-seventh Annual Convention of the New England Water Works Association was held at the Windsor Hotel, Montreal, P. Q., September 18–21, 1928.

The sessions of the Convention were held in Windsor Hall; the exhibits of the Associates were located in the Rose Room.

The office of president being vacant through the death of Gëorge A. Carpenter, Vice-President Arthur D. Weston presided.

Tuesday, September 18.

Morning Session.

The Chairman. The Forty-seventh Annual Convention will come to order.

I regret that His Worship, Mayor Houde of Montreal, is unable to be with us today; the Pro-Mayor, Mr. Mathewson, will address us in behalf of the city of Montreal. Mr. Mathewson. (*Applause.*)

(Remarks by J. A. Mathewson, Pro-Mayor, of the City of Montreal.)

Mr. Chairman, Ladies and Gentlemen: My first words must be ones of regret, echoing the sentiment just enunciated by Mr. Weston,— regret that our popular Mayor, Mr. Houde, is unable personally to come here this morning to greet you and to bid you welcome to our city of Montreal. Mr. Houde is prevented by circumstances beyond his control from being with you. But the city of Montreal seizes the opportunity, through my humble self, to say to you that you are abundantly welcome. We hope that this gathering will be fruitful of much good to you all.

Following Mayor Houde's tactful example, I must avoid all controversial subjects, and shall consequently avoid any discussion of our local water problem. We have had a matter here regarding the purchase of the Montreal Water & Power Company which caused some of us a great deal of mental disturbance, and the city has perhaps not yet calmed down from the effects.

There has been a further controversial subject which some of you must

have long enough memories to recall,— the question of reciprocity. Reciprocity is a word that here has taken on an artificial connotation in that, when reciprocity with the United States was proposed in 1911, the word was thought to imply political interference. Instead of us neighbors minding our own business and being friendly with each other, it was thought that we would mix in each other's internal affairs and matters of tariff, and that, it was thought, would lead to trouble.

But there is a reciprocity that cannot in any way be criticized. It is the reciprocity of ideas. You gentlemen, you engineers, coming from every state of the United States of America, are here to exchange ideas, to further learning, to spread information and knowledge, and to benefit mankind, — for you do benefit mankind in the most efficient and peculiar way. You are the public servants of whom we think only when you fail to serve us. If our water supply is good, abundant, constant, your existence is of no interest to the average citizen. But let him be denied his bath in the morning and Billingsgate can echo no words strong enough to condemn you and your assistants. (*Laughter.*)

But, gentlemen, some great good will come, I am sure, from your interchange of ideas here. And while your primary interest is in water, your coming to Montreal suggests a suspicion that you may be interested in other fluids, and we hope that the facilities for indulgence without license, the practice of liberty with moderation, will be enjoyed by you.

I intend to hold you no longer. I know you must get down to work, and in closing I should like to welcome you in the good old Canadian way, — may I say, the good old French-Canadian way, where the extended hand means the open heart. You are very welcome to Montreal. (*Applause.*)

Administrative Reports.

The Secretary, Frank J. Gifford, submitted his annual report. (See page 477.)

The Treasurer, Albert L. Sawyer, submitted his annual report. (See page 480.)

The Editor, Gordon M. Fair, submitted his annual report. (See page 483.)

The Report of the Finance Committee was read by the chairman. (See page 486.)

Award of Dexter Brackett Memorial Medal.

The report of the Committee on Award of the Dexter Brackett Memorial Medal for 1927 was presented by Charles W. Sherman.

August 15, 1928.

Executive Committee,
New England Water Works Association,
715 Tremont Temple,
Boston, Mass.

The Committee on the Dexter Brackett Medal Award for the year 1927 recommends that the medal be awarded to Mr. H. W. Clark for his paper on "The effect of pipes of different metals upon the quality of water supplied."

Respectfully submitted,

JOHN P. WENTWORTH, *Chairman.*
F. A. McINNES,
GEORGE A. SAMPSON.

MR. SHERMAN. Will Mr. Clark advance to the platform?

(*Mr. Clark comes to platform.*)

As I was a member of the original committee that solicited the fund to establish this medal and to secure the designs, and that had the first medal struck off, it is not so much of a burden to take over this presentation as it might be, because I am always very much interested in the award, and especially interested, of course, in its being made along the lines intended by the original committee, which we believed and still believe is the right line for the perpetuation of the ideals of Dexter Brackett. He was one of the most influential members of this Association, and one who did perhaps as much for it as any single man. Mr. Brackett was especially interested in making the Association a practical organization which would advance water-works knowledge, and the intent of the award of this medal was that it should be given for the paper which did the most, from among all the papers published during the year in the JOURNAL, to advance water-works knowledge.

It is a great pleasure to me to present this medal to Mr. Clark.

HARRY W. CLARK. Mr. President and Gentlemen: I assure you that I deeply appreciate the fact that a paper of mine has been considered worthy of this distinction.

One of the most pleasant and profitable experiences of my life has been my connection with this Association. I have learned very much at its meetings. It is thirty-four years since I became a member, and I think we can say, perhaps with more meaning and more significance than many others, that much water has flowed under the bridge during that period and many studies have been made in regard to that water. I have contributed a good many papers during that thirty-four years; sometimes because I had something to say, or at least thought I had, and sometimes because a hard-pressed chairman of a program committee insisted that a paper must be produced, and I have generally complied with that request.

When I joined this Association thirty-four years ago, it was a very different group of faces that I looked at from the group I see at this meeting

this morning or have met around the corridors of this hotel. In those days we had many members who have since passed on. There were superintendents of the type of Mr. Coggeshall of New Bedford, engineers such as F. P. Stearns and Desmond Fitzgerald, chemists and sanitarians such as Dr. Thomas N. Drown and William T. Sedgwick. The days of which I am speaking seem to me to have been the halcyon days of water-works research. They were the days when the Lawrence filters had just been started, when Hazen was about to build the Albany filters and when Fuller was about to begin those notable experiments at Louisville in regard to rapid filtration of water, when Walcott and Mills and Stearns were planning the Metropolitan water supply of Massachusetts and much other work of like nature was going on in different parts of the country. It was a great group of men, and they were all animated with the spirit of progress, and they were all, or practically all, members of this Association. But I feel sure that the same spirit of progress along all these water-works lines still animates this Association and that it still has many years of usefulness ahead of it.

I thank you. (*Applause.*)

Closing of Polls and Appointment of Tellers.

The Chairman. Have all those voted who desire to vote? (*No response.*) If so, I declare the polls closed, and appoint as a committee of tellers George F. Merrill of Ware, Charles J. Crump of Peabody, and H. W. Dotten of Winchester.

Committee Reports.

A progress report was made by Malcolm Pirnie, Chairman of the Sectional Committee on a Code for Pressure Piping. (See page 489.)

Progress reports were made by the following committees: Committee on Painting Standpipes and Committee on Grounding of Currents on House Plumbing to Act with a similar Committee of the American Water Works Association.

The representative at Tests of the Bureau of Standards, Harry W. Clark, presented a progress report. (See page 490.)

At 11.30 A.M. busses were taken for the works of the Consolidated Pipe Company, Ltd., of Montreal, where the party witnessed the operation of the plant in making cement pipe of various sizes. Luncheon was provided by the Company.

Afternoon Session.

The Report of the Committee on Cement-lined Pipe was presented by Robert Spurr Weston, chairman of the Committee. (See page 492.)

Robert Spurr Weston. The Committee asks that it be discharged.

THE CHAIRMAN. We are all very much interested in the report of this Committee. Has anybody any discussion that might be added to the report?

CALEB M. SAVILLE.* I should like to ask if it is possible to add some material or chemical for the use in the lining which will prevent its deterioration. Is it a practicable thing?

MR. WESTON. I have been told by one of the pipe manufacturers that they can make the cement coatings more resistant by a treatment which is rather expensive, however, and is not considered worth while in view of the fact that the surfaces so soon become indurate and fail to give up much of their material to the water. It is more practicable, in the few cases where the water attacks the pipe appreciably, to add something like lime or sodium silicate to the water and prevent the solution almost entirely. However, the manufacturers might consider the use of some wash that would change the inside of the cement lining to a silicate rather than a carbonate, but I have not gone into that matter far enough to decide whether or not the method is practicable.

MR. SAVILLE. Could the sodium silicate be put in with the cement lining? Would that make any particular difference?

MR. WESTON. How it would affect the setting of the cement, I do not know. My guess would be that the best way to apply it would be as a surface treatment after the coating has set.

A paper on "Protection of Catchment Areas" was read by John F. Skinner, Sanitary Engineer, Department of Public Works, Rochester, New York. Arthur D. Weston, Caleb M. Saville, Stephen H. Taylor, Francis T. Kemble, J. Walter Ackermann, and Earl Devendorf took part in the discussion.

The Report of the Committee on Cross-Connections was opened for discussion.

ROBERT SPURR WESTON. You will recall, gentlemen, that, last spring, the Committee on Cross-Connections presented a report to the Association which brought forth considerable discussion,—some of it adverse,—and that the report with its resolutions was not accepted and the resolutions which accompanied it were not adopted at that time. It was decided, however, to have the report printed in the June number of the JOURNAL and thus circulated among the members, thereby deferring action upon the report of the Committee until some further date.

The Committee has had some meetings since the time when the report was presented, and certain new factors have come into the problem which increase the difficulties of the Committee's work and upon which the members of the Committee are not yet in agreement.

Therefore, the Committee comes before you today, inviting discussion, that all possible light may be thrown upon this rather perplexing problem before the matter is taken up again. We hope that no action will be taken

*Manager and Chief Engineer, Board of Water Commissioners, Hartford, Conn.

today, nor until after we can discuss the matter at one of our Boston meetings where the attendance of our own members will be larger. We hope further that the matter will be deferred for final action until a letter ballot can be sent out stating the issues clearly and impartially and asking a vote of the whole Association upon this important matter.

The most important factor that has come up since the report was printed has been the development of a chlorinator that, apparently, is safe to use as a stand-by, for disinfecting non-potable supplies that are used for supplying fire pumps used in turn for sprinkler and fire-hydrant service in mills that are also supplied from the regular mains and services of the city, supplying potable water.

Formerly stand-by chlorinators could not be depended upon. They were manually operated, or if automatic they were not in operation at the time the fire occurred and before the pump was started. They were therefore considered unreliable. Recently, however, a chlorinator has been developed that discharges to waste continuously a certain small amount of chlorine, and then when the fire pump is started a steam- or electrically-operated switch turns the full dose of chlorine into the discharge of the pump, the dose being large enough to insure perfect disinfection of the water at the maximal rate that the pump is capable of discharging. This apparatus is being tried out now in the State of New York under practical conditions. Only a part of the Committee has seen or investigated or has been convinced of the reliability of this apparatus.

If the new chlorinator be reliable, we naturally ask if it does not change from hygienically non-potable to hygienically potable a raw water used for fire-reserve service, just as chlorination changes from non-potable to potable a water of a reservoir or a stream that, though good in appearance and suitable for drinking purposes, cannot be used without chlorination or some other kind of purification. This new device is important and must be considered. It offers a new line of defense against epidemics, against disease that may be introduced through the improper operation of fire-hydrant services or the failure of well-inspected, double check-valves of the most approved type.

The Committee wishes to consider its problem a little further. It has not yet agreed upon the importance of this factor or upon its effect upon the drafting of the resolutions that may be presented at a later date. We therefore come before you today asking you to give your most free and full opinions upon the whole subject; that the Committee may take note and gain from the discussion of this important subject.

Mr. Chairman, may I suggest that Mr. Devendorf of the State Department of Health of New York be invited to discuss this proposition.

EARL DEVENDORF.* At the outset I wish to say that I did not come here with any prepared discussion on this important subject of cross-connections. This subject is one of great interest to me and to the New York

*New York State Department of Health, Albany, N. Y.

State Department of Health, with which I am connected. The problem of cross-connections in our state has been one of considerable magnitude and has been under consideration for the past three years.

In New York State, the Public Health Council, which is a body created by the Legislature, has the authority to adopt a Sanitary Code that has the effect and force of law.

The Public Health Council, after prolonged and deliberate study of the problem of cross-connections between potable and non-potable water supplies, enacted in November, 1925, Regulations 15-a and 15-b of Chapter VII of the Sanitary Code requiring by July 1, 1928, the elimination of such cross-connections in New York State. Subsequent events have emphasized the menace to health created by such cross-connections. Sections 15-a and 15-b read as follows:

SANITARY CODE — CHAPTER VII.

MISCELLANEOUS.

Regulation 15-a. Certain cross-connections between water supplies not permitted. No officer, board, corporation or other person or group of persons, owning or having the management or control of any potable water supply furnished to any municipality or water district, shall permit after July 1, 1926, any physical connection between the distribution system of such supply and that of any other water supply, unless such other water supply is regularly examined as to its quality by those in charge of the potable water supply to which the connection is made and is also found to be potable. This prohibition shall apply to all water distribution systems either inside or outside of any building or buildings.

Provided, that, where such physical connections now include two gate valves with indicator posts, two check valves of the Special Factory Mutual Fire Insurance design or equivalent with drip cocks and gauges for testing, all located in a vault of water-tight construction accessible for ready inspection, the date of discontinuance may be extended until July 1, 1928.

Regulation 15-b. Permissible arrangements where dual supplies are used. If a potable water supply is used as an auxiliary supply delivered to an elevated tank or to a suction tank, which tank is also supplied with water from a source with which cross-connections are not permitted by regulation 15-a, such tank shall be open to atmospheric pressure and the potable water supply shall be discharged at an elevation above the high water line of the tank.

Since these regulations were enacted, protests by certain representatives of industry have been made to the Public Health Council. Following such protests, the Council has repeatedly consulted manufacturers, health officials, water-supply officials, sanitary engineers, fire-protection engineers and insurance-rating officials. As a result, it has become convinced that the complete severance of potable and polluted waters is demanded for the protection of the public health, and that this can be accomplished without increasing fire hazard to life or property.

The Council believes therefore that Regulations 15-a and 15-b of Chapter VII of the Sanitary Code were wisely conceived and that there exists no adequate reason for their modification.

In the consideration of any proposition, over which there is a controversy or difference of opinion, there are generally two angles or viewpoints. Before a mutual agreement can be arrived at, it is essential that both viewpoints be thoroughly understood.

As a result of numerous conferences with representatives of the industries and the insurance authorities, where we endeavored to sit down and put our feet under the table, so to speak, and study the problem together, it has been our experience that in practically all cases, satisfactory substitutes can be provided by the industries at a reasonable cost, and a considerable number of our municipalities have secured the elimination of such cross-connections between potable supplies and polluted auxiliary supplies.

With the approach of the time limit of July 1 of this year, as set forth in the Sanitary Code for the elimination of cross-connections, the Department received numerous letters from municipalities and industries throughout the state requesting an extension of time. In a number of instances, the industries had already taken steps to have an elevated tank or suction tank constructed, but the work could not be completed by the date set forth in the Code. It appeared only reasonable to grant such extension as, in a large number of instances, it was physically impossible to have the work completed in the time specified. About this same time, the fire-pump chlorinator that Mr. Weston has just spoken of was developed, and it was necessary to have installed and tested this apparatus in one of the industrial plants in our state. Accordingly the Public Health Council at its meeting held on June 27, 1928, authorized the postponing of carrying out of regulations 15-a and 15-b of Chapter VII of the Sanitary Code until January 1, 1929.

As a result of tests of the special, automatic, stop-and-start fire-pump chlorinator, we found this capable of effectively chlorinating an auxiliary supply under intermittent operation of fire pumps and rendering such auxiliary supply potable, provided it is not too grossly polluted. Such installation must, however, meet the following departmental requirements:

1. The water supply must not be so grossly polluted that it cannot be effectively chlorinated.

2. The fire pump must either take suction from an open well or pump, or there must be a municipal water supply available having a pressure at least three times as great as the pressure on the suction of the pump.

3. The chlorination equipment must be of a type approved by this Department and so equipped as to continuously waste a small amount of chlorine solution and provided with solenoid or steam-operated valves so regulated that immediately upon the starting of the pump it will apply chlorine at a rate of not less than twenty pounds of chlorine per million gallons of water pumped.

4. Platform scales must be provided for checking the loss of weight of chlorine.

5. Plans of the installation, together with a report and sufficient data to pass upon it, must be submitted for approval to both the local water authorities and to the State Department of Health.

6. Reports of the results of daily ortho-tolidin tests of the chlorine solution wasted

and the amount of chlorine wasted or used per day must be submitted at least monthly to the municipal water-supply authorities.

7. Chlorinators on all auxiliary, industrial or fire supplies must be inspected regularly and at frequent intervals by local water-supply authorities.

8. The cross-connection between a potable municipal supply and a chlorinated, auxiliary, industrial or fire supply must be equipped with double check-valves of the "all bronze" type placed in an accessible chamber and properly equipped for testing and inspection. Such check-valves must be inspected and tested at least monthly and taken apart, thoroughly cleaned and any worn parts replaced at least yearly.

9. Discharge valves on the fire pumps must be closed whenever the pumps are turned over for testing.

10. Any approval by the municipal and water-supply authorities or this Department will be given only on condition that the chlorination apparatus is satisfactorily installed, operated and maintained at all times.

In a way we may compare the installation of the all-bronze type double check-valves and the fire-pump chlorinator with the treatment of water by filtration and chlorination. In both instances the chlorination process is the finishing process, and main reliance is placed on the filter plant and all-bronze type of check-valves. In a way the analogy is, perhaps, not so badly drawn. We have considered that with the installation of the double all-bronze type of check-valves and the fire-pump chlorinator, there would be a very remote possibility that both should fail at the same time. Moreover, the Code provides that we shall issue the permit which shall also be approved by the local water department on the condition that daily tests are made and that they shall be reported monthly to the local water-department authorities and the state commissioner of health. If, in the future, our experience at any particular plant indicates that they are not maintaining the chlorinator satisfactorily, the permit can be revoked and the industry required to completely eliminate the cross-connections.

There is one point I wish to bring out, however, namely, that every effort is being made to eliminate cross-connections, if possible or if practical. Our experience is that in nearly all instances some satisfactory arrangement or substitution can be provided at a reasonable cost. There are, however, a few instances where, while not impossible, it is very difficult, if not impractical, to eliminate cross-connection. In these instances, we feel that the installation of a fire-pump chlorinator with the all-bronze type of check-valves will answer the needs. One of these instances I might mention, occurred in the case of one of the industries of the state where the cost of providing a system which would be approved by the fire authorities involved an expenditure of some $44,000. Moreover, the industry in this case was very reluctant to eliminate the use of the auxiliary supply on account of the large capital invested in their plant and the admittedly inferior fire protection afforded by any plan which called for the elimination of this auxiliary supply. In this plant, the installation of a fire-pump chlorinator with all-bronze type of check-valves on the cross-connection has been approved.

In closing I wish to state that the coöperation we have secured from the representatives of the industries in the state and from the fire-insurance authorities has been excellent. Once the problem has been understood, the industries and insurance authorities have given the Department their fullest coöperation.

H. T. GIDLEY.* I should like to ask whether the New York State Department of Health would allow an entirely new plant to put in a cross-connection.

MR. DEVENDORF. Yes, I believe so. But if practical we try to prevail on the industry not to have any cross-connection. It would be hard to believe that a new industry, just starting out, would have to lay out its system to start with so that it would not be practicable in some way to eliminate the cross-connection. Of course, the original code did provide that after a certain date — I believe it was July 1, 1927 — any cross-connection not already provided with the all-bronze type of check-valve should be eliminated at that date, and those that are still in existence are in violation of the Code.

ROGER W. ESTY.† I think that cross-connections can be eliminated in part and that the authority should be given, perhaps, to the State Department of Public Health to assist in the complete elimination. If it is left entirely to the local authorities, it may be rather difficult to see that elimination is accomplished. Politics a great many times enter into such things. But if the local authorities have the backing of some state department, I think that satisfactory results can be obtained.

In regard to double check-valves, I made some tests recently of some fire check-valves with the view of installing them instead of the regular type fire-meters. We have three of these valves; two of them had bronze seats and bronze valves; one had a bronze seat and rubber valve. In some of the tests that we ran, with various-sized meters on the line, — $1\frac{1}{2}$-, 1- and $\frac{3}{4}$-in. meters, — we endeavored to find out where the breaking point would come and to see what result would be obtained in regard to tightness. We found under some circumstances, on $\frac{1}{8}$-in. down to $\frac{1}{16}$-in. streams, that we would only obtain about 90 per cent. of the water, and we found in numerous tests that the meters indicated leakage through the check-valve itself. This shows that, regardless of how carefully a check-valve may be constructed and how responsive it may be, there is the possibility of water getting through at times. I do not think we should depend upon check-valves. We should try to eliminate the cross-connection altogether.

FRANCIS T. KEMBLE.‡ In my opinion cross-connections should not exist.

They are found today in many factories all around the country, not used for fire protection alone but for other purposes. I have known water pumped from highly contaminated streams for flushing, for condenser

*Treasurer and Superintendent, Fair Haven Water Co., Fair Haven, Mass.
†Superintendent of Water Works, Danvers, Mass.
‡Secretary, New Rochelle Water Co., New Rochelle, N. Y.

cooling and even to prime pumps lifting sewage, sometimes with a check-valve, sometimes with no check, only a valve or stop cock. In the event of the head on the street mains falling below the pump pressure, contaminated water could be forced into the mains, if a check-valve failed to work or the stop cock be not closed tight.

HUGH MCLEAN.* It seems to me, from the size of this gathering that we are dealing with a problem that a great many of us are greatly interested in. Probably a majority of those present came to listen to the discussion, hoping that some final recommendation would be made that could be adopted. Cross-connections are a problem that is confronting most of the water departments.

The last time we discussed this problem, the request was made for the Committee to bring in something that could be adopted, if I remember correctly, and yet we seem today to be as far from a solution as ever.

Unless we have the coöperation of the state with the local water departments, what can we accomplish? The question before us is: "Are we going to tolerate the pumping of polluted water into the mains?" It seems to me that we should not hesitate about the adoption of recommendations that would prohibit a practice that makes this possible. Surely our Committee can arrive at some recommendation that will be uniformly adopted, and will prohibit the pumping into the mains of polluted water.

I have been studying water department affairs for a great many years. And as my mind runs on this topic, if we have not the courage to adopt resolutions that ought to be adopted, some great influence must be prevailing on us not to impose the expense on manufacturers. It is simply a question whether or not we have the courage of our convictions. We are devoting our time, our thoughts, our minds, to the perfection of water systems of our various municipalities, expending thousands — yes, hundreds of thousands of dollars, and perfecting our water supplies so that the water will be pure and free from contamination. Shall we allow someone the privilege of pumping into it a contaminated water?

Let us arrive at some decision, make a recommendation and have the state enact a law prohibitive of pumping into the mains contaminated water where it may affect the human beings who are consuming supposedly pure drinking water, which possibly may be made impure by pumping foul, filthy water from a canal or a river, at high, flood tide, just as the fire happens to be. (*Applause.*)

W. C. HAWLEY.† The fire-pump chlorinator is a very interesting proposition, but I wonder what assurance we have that the new chlorinator will be reliable and ready to operate satisfactorily when it is needed. I had an enlightening experience this summer. I have a cottage which is occupied by my family in the summer. It is situated in a community of something over one hundred cottages. The water supply has been pumped from a

*Water Commissioner, Holyoke, Mass.
†Chief Engineer and Superintendent, Pennsylvania Water Co., Wilkinsburg, Pa.

neighboring polluted source for some years, and I have always provided a solution of chlorine which the family has added to the water before using. Last year the State Department of Health insisted that the little water works, which is owned and operated by an individual, should provide a chlorinator, and this year we thought the supply would be pure. However, before my family left, I insisted that they should take along a bottle of chlorinated water and use it, because I feared that the chlorinator would not be operated as it should be. I visited this place in August, and about the first thing I did was to go to the pumping station and see how things stood. I found the pump running along merrily, with the chlorinator out of order. The man was working at it. He assured me that he had had a great deal of trouble with it. I do not think it was the fault of the chlorinator, because it is a well-known make, and it ought to be perfectly reliable. But the fact remains that it had been out of order at various times and the operator had continued to pump water.

What assurance have we that a chlorinator on a supply of this kind will be operated any better than this one was? I personally am very much opposed to cross-connections.

CALEB M. SAVILLE.* I do not know that it is necessary for me to make much of a statement now, as I have said enough on this subject at various other times, and I think it is unnecessary to prolong this discussion. As I understand, the time is limited and we have much else to do.

To bring the matter to a head, I move that this matter be laid on the table for further discussion and taken up at the next meeting or some subsequent meeting of the NEW ENGLAND WATER WORKS ASSOCIATION, as the order of business for that meeting.

(The motion was duly seconded and carried.)

Greetings to Walter H. Richards.

THE CHAIRMAN. Mr. Saville, there is one of our members of long standing, to whom you called my attention the other day. I think it would be a nice thing to let men of his type know that we are thinking of them. They have been members for a great many years and have now reached the age where they can't always attend our meetings and our conventions. Will you just say a few words in regard to this matter?

CALEB M. SAVILLE. I am very glad that you brought this matter up. I spoke in an informal way to our chairman of Walter H. Richards of New London. Mr. Richards, if not a charter member, is at least a member within one or two meetings after this Association was incorporated or came into being. Mr. Richards is now an honorary member. For a great many years, prior to becoming superintendent of the water works of New London, he was connected, as a chief assistant, with J. T. Fanning, one of the older water-works engineers. We now have all too few men of his type,

*Chief Engineer, Board of Water Commissioners, Hartford, Conn.

who are familiar with the work done by Mr. Fanning, and, if in order, I would like to suggest that some word be sent to Mr. Richards. He is getting along in years and has less to occupy himself than formerly when in active practice. I am sure he would be much pleased to be remembered by this Convention. I think it would be helpful to him now if some word from this Association could be sent to him, to the effect that the Association thought of him and that we would like to send a word of greeting to him. I don't know that I need to present this as a motion, but I would like to make it as a suggestion. I am sure that the chairman can handle this matter in a very proper way, if authorized.

THE CHAIRMAN. Mr. Saville offers a motion that we send a word of greeting and best wishes to this member. Does anybody wish to second this motion?

STEPHEN H. TAYLOR.* I remember Mr. Richards very well as an editor of the Association at the time that Mr. Coggeshall was secretary, and I think it would be a very fitting thing to send him the proposed greetings. If it is necessary that the motion should be decided upon by vote, I am pleased to second the motion.

(*The motion is unanimously carried.*)

WEDNESDAY, SEPTEMBER 19.

Morning Session.

A paper on "Unusual Methods of Water Purification" was read by M. E. Flentje, Superintendent of Purification, Community Water Service Company, New York City. Arthur D. Weston, Wellington Donaldson and J. Walter Ackermann participated in the discussion.

A paper on "Recent Developments in Water Purification" was read by Wellington Donaldson, of Fuller and McClintock, Consulting Engineers, New York City. Arthur D. Weston, Charles W. Sherman, M. N. Baker, J. Walter Ackermann, H. W. Clark and N. J. Howard took part in the discussion.

A paper on "The Extension of the Works of the Greenwich Water Company, Greenwich, Connecticut," illustrated with stereopticon views, was read by Dana M. Wood, of Stone & Webster, Engineers, Boston, Mass. Arthur D. Weston and John F. Skinner took part in the discussion.

A paper on "The New Water Purification Works at Greenwich, Connecticut," illustrated with stereopticon views, prepared by E. Sherman Chase of Metcalf and Eddy, Consulting Engineers, Boston, was read by Charles W. Sherman. Arthur D. Weston, W. J. Wilson, Dana M. Wood, George F. Merrill, N. J. Howard, A. C. Chandler and William Gore participated in the discussion.

*Superintendent of Water Works, New Bedford, Mass.

Afternoon Session.

A paper on "The Effect of Sunlight on the Determination of Chlorine by the Ortho-tolidin Method," prepared by F. R. McCrumb and W. R. Kenny, of the Research Laboratory of The La Motte Chemical Products Company, Baltimore, Md., was read. The paper was discussed by N. J. Howard.

A paper on "The Equipment and Operation of Water Works Laboratories," prepared by Melvin C. Whipple, Assistant Professor of Sanitary Chemistry, Harvard University, Cambridge, Mass., was read by Gordon M. Fair. Arthur D. Weston, Robert Spurr Weston and A. U. Sanderson took part in the discussion.

A paper on "Zeolite Water-softening for Municipal Supplies," illustrated with stereopticon views, was read by F. D. Kneeland, Chemist, Ohio Valley Water Company, McKees Rocks, Penn.

Superintendents' Sessions.

During the morning and afternoon of this day, separate sessions were held at which subjects of especial interest to superintendents were discussed. Stephen H. Taylor, Past-president of the Association, and Superintendent of the New Bedford Water Works, presided.

Morning Session.

The general subject for this session was "Distribution." The discussion was opened by a paper on "Some Distribution Problems" by Fred B. Nelson, Assistant Engineer, Department of Water Supply, Gas and Electricity, New York City. William W. Brush, David A. Heffernan, W. C. Hawley, John T. Robertson, Theodore Bristol, Percy R. Sanders, Henry T. Gidley, H. O. Lacount, Charles J. Crump, E. W. Hopkins, Caleb M. Saville, Frank P. Hall, Roger W. Esty, Mr. Judkins (in charge of water works at Franklin, New Hampshire), John C. Schlicht, S. G. Wiley and George F. Wieghardt participated in the discussion.

A paper on "Water Services" was read by William G. Schneider, of the Copper and Brass Research Association, New York City. Theodore L. Bristol, David A. Heffernan, Mr. Judkins, Edwin H. Arnold, Marshall B. Palmer, G. E. Hawkins, W. C. Hawley, Joseph A. Hoy, and Henry T. Gidley took part in the discussion.

Afternoon Session.

The opening subject for discussion at this session was "Electrolysis of Water Mains." A paper on "Electrolysis Investigation," prepared by C. F. Meyerherm of Albert F. Ganz, Inc., was read by D. W. Barron. This general subject was discussed by Stephen H. Taylor, Charles W. Sherman, Roswell M. Roper, J. Walter Ackermann, S. G. Wiley, John D. Capron,

W. C. Hawley, Caleb M. Saville, David A. Heffernan, W. J. Wilson, Frank A. McInnes, H. N. Blunt, C. J. Clogston, Charles J. Crump, Roger W. Esty, Theodore L. Bristol, Walter P. Schwabe, Henry T. Gidley, Henry V. Macksey, C. Stephen, C. R. Weagraff and Charles W. Mowry.

The matter of "Revenue from Fire Services for Factory Protection," the subject of "Collecting a Minimum Rate where Water is Shut Off," and other subjects of interest to superintendents, were discussed by W. C. Hawley, C. M. Saville, C. W. Mowry, W. J. Wilson, Roger W. Esty, Theodore L. Bristol, A. U. Sanderson, Charles J. Crump, D. M. Hanna and Franklin Henshaw.

Evening Session.

ARTHUR D. WESTON. Even though it is rather late in the day, we want to welcome all of the American Water Works members who are at the Convention with us. I understand that some seventy members are registered and I want them to feel that they are a part of the NEW ENGLAND WATER WORKS ASSOCIATION as far as this Convention is concerned.

We have combined the general sessions and superintendents' sessions tonight, because we feel that the papers dealing with the pumping station in Montreal and also the filtration works are subjects that all of us are interested in. Immediately following these two papers we shall resume the Superintendents' Conference. I am going to turn the gavel over to Mr. Taylor, because we really consider these papers now as being included in the Superintendents' Conference.

(*Stephen H. Taylor in the Chair.*)

A paper on "The McTavish Street Pumping Station" was read by Charles J. Des Baillets, Chief Engineer, Montreal Water Board, Montreal, Canada.

A paper on "The Montreal Filtration Works," prepared by Frederick E. Field, Division Engineer, Montreal Water Board, and John H. Harrington, Chemist at Filtration Plant, was read by Mr. Field.

After the close of these papers, the Superintendents' Conference was resumed.

The opening subject discussed was "The Effect of Flushometer Valves upon Water Works Practice." Other subjects of interest to superintendents were also discussed. George A. King, David A. Heffernan, Roger W. Esty, George C. Brehm, George F. Merrill, Dana M. Wood, Charles J. Crump, W. J. Wilson, Percy R. Sanders, George F. Wieghardt, J. P. Miller, Joseph A. Hoy, James H. Towers, Frank P. Hall, Arthur D. Weston, Marshall B. Palmer, F. J. O'Brien, Theodore L. Bristol and William H. Powell took part in the discussion.

THURSDAY, SEPTEMBER 20.

Morning Session.

REPORTS OF COMMITTEES.

Frank A. McInnes, Consulting Engineer, Boston, submitted reports for the following committees: (See page 487.)

Standardization of Cast-iron Pipe and Special Castings.

Simplification of Manhole Frames and Covers.

Specifications for Cast-iron Pipe and Special Castings.

Standardization of Pipe Flanges and Fittings.

A paper on "Factors in the Design of Distribution Systems," was read by V. Bernard Siems, Vice-President and Chief Engineer, Detwiler and Company, Inc., New York City. Arthur D. Weston, J. Walter Ackermann, Henry V. Macksey, Henry A. Symonds, Owen J. Eagan and Hugh McLean took part in the discussion.

After the close of the morning session, a visit was made to the Montreal Water Purification Plant, where an inspection was made. Luncheon was provided by courtesy of the city of Montreal.

Afternoon Session.

A paper on "The Oxy-Acetylene Process in Modern Industry," was read by R. W. Boggs, The Linde Air Products Company, New York City. The paper was illustrated by stereopticon views. H. O. Lacount discussed the paper.

At this point a general discussion was opened on the subject, "Are the present specifications dealing with fire hydrants and valves with special reference to valve stems satisfactory?" The discussion was opened by Frank A. McInnes and participated in by H. O. Lacount, Robert Spurr Weston, J. T. Robertson, S. G. Wiley, D. M. Hanna, George C. Brehm, Charles J. Crump, W. E. McDonald, W. C. Hawley, M. J. Rutledge, Arthur D. Weston and Henry V. Macksey.

FRIDAY, SEPTEMBER 21.

Morning Session.

A paper on "A New Pipe for Water Mains," illustrated by stereopticon views, was ready by R. W. Mitchell, Consulting Engineer, The Asphalto-Concrete Corporation, New York City. Dana M. Wood, J. Walter Ackermann, John F. Skinner and George F. Merrill took part in the discussion.

Report of Tellers of Election.

Total number of ballots cast	299
President.	
ARTHUR D. WESTON	294
Scattering	2
Blank	3
Vice-President.	
GEORGE H. FINNERAN	292
Scattering	1
Blank	6
Directors.	
RICHARD H. ELLIS	287
KARL R. KENNISON	291
Scattering	2
Blank	18
Treasurer.	
ALBERT L. SAWYER	290
Scattering	1
Blank	8

GEORGE F. MERRILL, *Chairman.*
CHARLES J. CRUMP,
HARRY W. DOTTEN.

THE CHAIRMAN. You have heard the report of your tellers. What is your pleasure?

(*On motion of Theodore L. Bristol, duly seconded by Charles J. Crump, the report of the Committee was accepted.*)

President's Address.

Arthur D. Weston. The New England Water Works Association, by its Constitution, requires the retiring president to deliver an address at the Annual Meeting, but makes no provision for an address by the Acting President.

As you know, George A. Carpenter, former City Engineer of Pawtucket, Rhode Island, was elected president of this Association at the meeting held a year ago at the Hotel Statler, Boston.

Mr. Carpenter was shortly after stricken with an incurable disease and died on December 15, 1927.

Under the circumstances, the senior vice-president, as acting president, was obliged to fill the term of office, and it is, therefore, most fitting that in place of the customary president's address, which should be given at this time, I take the opportunity to remind you of Mr. Carpenter's work for this Association.

Mr. Carpenter was active on many important committees, was ever ready to carry out the various tasks allotted to him and, because of his ability, faithfulness and personality, was one of the most beloved officers that this Association has ever had. If the work of this Association during the past year has been successful, this success is due, chiefly, to much of the planning of Mr. Carpenter previous to his death. If the work has not been a success, it is simply because those who tried to carry out Mr. Carpenter's plans were unfortunately not gifted with Mr. Carpenter's ability.

May we leave this Convention with a kindly thought and loving appreciation of the work of our departed president, George A. Carpenter.

Percy R. Sanders. I move that we stand a second or two in respect to Mr. Carpenter's memory.

The Chairman. I think that it is not necessary to put that to a vote; it is a good plan, and I would like to see it carried out. We shall all rise.

(*All members stand for a moment.*)

Before closing the Convention, is there any further business to come before the Convention?

Resolutions of Thanks.

Hugh McLean. I think it is fitting at this time to offer a motion in appreciation of the courtesies that have been shown us by the Water Works Manufacturers Association, and I would like to submit the following resolution:

Resolved, that the thanks of the New England Water Works Association be extended to the Water Works Manufacturers Association, and its able officers, for the very splendid entertainment which they were able to give us at the Forty-seventh Annual Convention.

Richard H. Ellis. Mr. President, I would like to present the following resolution:

Resolved, that the thanks of the NEW ENGLAND WATER WORKS ASSOCIATION be extended to His Worship Camillien Houde, Mayor of Montreal; Charles J. Des Baillets, Chief Engineer, Montreal Water Board; Frederick E. Field, Division Engineer, Montreal Water Board; Drummond McCall Co., Ltd., Montreal, Quebec; Thomas W. Lesage, Engineer, Water Works, Montreal, Quebec; W. S. Lea, Consulting Engineer, Montreal, Quebec; James O. Meadows, Consulting Engineer, Montreal, Quebec; C. L. Scofield, Manager, Sprinklered Risk Department of Canadian Fire Underwriters' Association, Montreal, Quebec, for the many courtesies which they have extended to this Association at this Forty-seventh Annual Convention.

GEORGE C. BREHM. Mr. President, I would like to submit the following resolution:

Resolved, that the thanks of the NEW ENGLAND WATER WORKS ASSOCIATION be extended to the Consolidated Pipe Company, Limited, Montreal, and R. W. Mitchell, Consulting Engineer, The Asphalto-Concrete Corporation, New York City, for the very splendid entertainment they were able to give us at the Forty-seventh Annual Convention.

THE CHAIRMAN. You have heard the resolutions as read by Messrs. McLean, Ellis and Brehm. What is your pleasure?

(*Upon motion of Hugh McLean, duly seconded, it was VOTED that the resolutions be adopted.*)

The PRESIDENT-ELECT. During the coming year I hope to carry out some of the traditions of the NEW ENGLAND WATER WORKS ASSOCIATION and help build up the Association. When I look back on the names of the officers of the Association in past years, I must admit that it is no small task to follow along in their footsteps. I believe that the work of the Association — in fact, any association — can only be accomplished when the full membership coöperates with the officers. My mailing address you all have in your directory. There will be a new directory published during the year 1929, and we shall have in that the names and addresses of all the members at the time of publication. I hope that you will feel free to correspond with all the officers, and I hope that if you have even a suggestion of a thought that may develop into assistance to the Association, you will feel free to write the officers. I can promise you that any suggestion will be kindly received and will be thoroughly considered.

The question has been raised as to whether we should or should not hold a meeting during the winter in some place other than the city of Boston. I would like to have you take that thought home with you and write to me what you think about it. In some of the New England states they feel as though we should at least visit them once during the year.

Another thing about which I would like to have you think and tell me is that perhaps we have one more meeting during the year than we usually do. We can have as many as we wish, according to our Constitution, but we usually have had the first meeting in November and the last meeting in

March, and outside of the Convention, which has come in September, those are the only meetings. The suggestion has been made that we have one additional meeting, perhaps in some other city than Boston, and have it what we might term a subject meeting; that is, a meeting devoted to one subject. I understand that in Connecticut they are very much interested in the subject of meters. If you feel in general that this is a good plan, we would be only too glad to arrange for a meeting some place in Connecticut and have "meters" as the subject matter of that meeting. Then we can take up some other subject at some other place.

I would also like to get suggestions relative to the formation of committees. Are there any subjects that we are not considering now but should consider? You have in this program the names of all the standing committees of this Association. If you feel that there should be other committees or that there are other subjects which should be considered, let your officers know about them.

We would like to hear from you regarding the location of the June outing, and also of the next Convention. The only way that the Executive Committee can be properly guided is to get suggestions from all members.

New Members.

Secretary Gifford. I have to announce the election of the following new members: Charles R. Weagraff, Salamanca, N. Y.; Robert A. Harrington, Greenfield, Mass.; John W. Vaughan, Johnstown, N. Y.; John C. Moore, West Falmouth, Mass.; Thurman W. Dix, Barre, Vt.; Burt B. Hodgman, East Orange, N. J.

At the present time there are 816 active members, and the total membership of the Association, including active and honorary members and associates, is well over 900.

The President. Is there any further business to be brought before this Convention? (*No response.*) If not, I declare the Forty-seventh Annual Convention closed.

(*The Convention adjourned at 10:50* A.M., *Friday, September 21, 1928.*)

On Friday afternoon a party left the city by automobile at 4 P.M., for Lachine, where a boat was taken for the return trip to Montreal through the Lachine Rapids. This trip was made possible through the courtesy of the Water Works Manufacturers Association.

Annual Report of the Secretary.

Mr. President and Gentlemen of the New England Water Works Association, — The Secretary submits herewith the following report of the changes in membership during the past fiscal year, and the general condition of the Association.

The present membership is 808, constituted as follows: 10 Honorary, 688 Members, 1 Junior, 11 Corporate Members, 98 Associates. The detailed changes are as follows:

MEMBERSHIP.

September 1, 1927.	Honorary Members		11		
	Withdrawals:				
	Died	1	1		10
September 1, 1927.	Total Members		673		
	Withdrawals:				
	Resigned	10			
	Dropped	4			
	Died	14	28	645	
	Elected:				
	September, 1927	11			
	November, 1927	7			
	March, 1928	11			
	April, 1928	1			
	June, 1928	4			
	August, 1928	3	37		
	Reinstated:				
	Dropped in 1917	1			
	Dropped in 1919	1			
	Dropped in 1923	1			
	Dropped in 1924–25	1			
	Resigned in 1917	1			
	Resigned in 1919	1			
	Resigned in 1923	1	7	44	689
September 1, 1927.	Total Juniors		1		
September 1, 1928.	Total Juniors				1
September 1, 1927.	Total Associates		87		
	Withdrawals:				
	Resignations	3	3	84	
	Elected:				
	September, 1927	9			
	February, 1928	1			
	April, 1928	1			
	June, 1928	1			
				12	

	Reinstated:			
	Dropped in 1902	1		
	Resigned in 1918	1	2	98
September 1, 1927.	Total Corporates		11	
September 1, 1928.	Total Corporates			11
September 1, 1928.	Total Membership			809
September 1, 1927.	Total Membership			783
	Net gain			26

Members Elected from September 1, 1927, to September 1, 1928.

Members.

September 13 to 16, 1927. E. L. Bean, S. L. Briggs, F. Perry Close, A. W. P. Cobb, E. C. Craig, F. E. Driscoll, J. P. Lynch, A. B. Morrill, J. H. Read, J. T. Robertson, G. M. Warren. (11)

November 9, 1927. R. R. Bradbury, G. A. Chamberlain, J. J. Ducey, P. M. Putnam, J. H. Robinson, T. E. Sears, G. A. Walker. (7)

March 14, 1928. B. C. Bussey, L. M. Gentleman, J. D. Guillemette, E. J. Guiney, Thomas Hargreaves, L. H. Kunhardt, T. P. McDermott, F. P. Morse, W. F. Rockwell, F. H. Torrey, W. E. Young. (11)

April 17, 1928. Caleb S. Harriman. (1)

June 26, 1928. J. D. Egan, L. M. Fisher, P. F. Howard, L. T. McMahon. (4)

August 18, 1928. D. L. Macdonald, A. W. Read, Abel Reynolds. (3)

Reinstated:		
Dropped in 1917 (E. F. Hughes)	1	
Dropped in 1919 (G. H. Chase)	1	
Dropped in 1923 (C. A. Bingham)	1	
Dropped in 1924–25 (E. J. Looney)	1	
Resigned in 1917 (A. S. Malcomson)	1	
Resigned in 1919 (Dana M. Wood)	1	
Resigned in 1923 (W. I. Brown)	1	7

Associates.

September 13 to 16, 1927. American Brass Company; Barber-Greene Company (E. F. Lamprey, Cambridge, Mass.); Chicago Bridge and Iron Works; Federal Meter Corporation; General Pipe Cleaning Company; Giant Mfg. Company; W. & L. E. Gurley; LaMotte Chemical Products Company; National Cast Iron Pipe Company. (9)

February 9, 1928. Antonio Mogavero. (1)

April 17, 1928. Hauck Manufacturing Company. (1)

June 26, 1928. The Herbert Kennedy Company. (1)

Reinstated:		
Dropped in 1902 (The Fairbanks Company)	1	
Resigned in 1918 (Pratt & Cady Co., Inc.)	1	2

Honorary Member.

Died: Francis E. Hall. (1)

Members.

Died: T. H. Barnes, G. A. Carpenter, C. E. Chandler, F. L. Cole, A. W. Dudley, S. A. Holton, H. W. Horne, George Mitchell, E. L. Sampson, M. A. Sinclair, G. H. Snell, C. N. Taylor, S. H. Thorndike, J. A. Tilden. (14)

Resigned: F. S. Bailey, J. Frank Ellis, C. R. Henderson, T. W. Jenkins, C. R. Jones, D. H. Maury, A. E. Morgan, J. J. Turner, H. T. Wheelock, F. R. Woodward. (10)
Dropped: W. W. Albee, Stephen Barden, F. H. Luce, J. H. Reynolds. (4)

Associates.

Resigned: Automatic Hose Coupling Company, Inc.; B. Nicoll & Company, Inc.: W. P. Taylor & Company. (3)

Receipts for Fiscal Year, September 1, 1927, to September 1, 1928.

Entrance Fees			$241.00
Annual Dues:			
Members	$2 949.10		
Juniors	3.00		
Associates	1 240.00		
Corporates	90.00	$4 282.10	
Fractional Dues:			
Members	$86.00		
Associates	45.00	131.00	
Past Dues		111.00	
Prepaid Dues (1928–1929):			
Members	$54.00		
Prepaid Fractional Dues (1928–29):			
Members	6.00		
Prepaid Fractional Dues (1929–1930):			
Members	4.00	64.00	
Total Dues			$4 588.10
Advertisements			4 158.00
Subscriptions			518.98
JOURNALS sold			332.76
Sundries			888.44
Total receipts			$10 727.28
There is due the Association:			
Advertisements		$77.00	
JOURNALS		2.50	
Reprints		38.35	
Subscriptions		57.00	174.85
Total			$10 902.13

Respectfully submitted,

FRANK J. GIFFORD, *Secretary.*

Annual Report of the Treasurer.

September 1, 1927, to August 31, 1928.

The President and Members of the New England Water Works Association:

I herewith submit my report as treasurer for the year ending August 31, 1928.

Receipts.

September 1, 1927 — Cash on hand			$3 275.30
Initiation fees	$241.00		
Dues	4 588.10	$4 829.10	
Interest and dividends			762.49
Journal:			
Advertisements	$4 158.00		
Subscriptions	518.98		
Sale of Journals	332.76		
Sale of reprints	79.55		
Filtration forms	3.60	5 092.89	
Miscellaneous:			
Certificates of membership	$1.50		
Standard specifications	32.50		
Meter sheets	2.80		
Sale of buttons	1.00		
Sale of cuts	5.00	42.80	
Total receipts			10 727.28
			$14 002.58

Expenditures.

Journal:			
Advertising agent's salary and commission	$139.20		
Editor's salary	625.00		
Editor's expense	15.82		
Plates	605.75		
Printing	3 913.97		
Reporting	513.36		
Reprints	887.20		
Stationery and postage	145.99		
Sundries	3.15	$6 849.44	
Amount brought forward			$6 849.44
Office:			
Affiliated Technical Societies	$2 040.00		
Printing, stationery and postage	295.28		
Secretary's salary	400.00		
Secretary's expense	167.96		
Sundries	5.71	2 908.95	
Meetings and Committees:			
Dinners for guests	$32.75		
Badges	114.53		
Printing, stationery and postage	568.48		
Stereopticon	85.00		
Sundries	194.55	995.31	

Miscellaneous:			
Certificates of membership	$.50		
Exchange	1.80		
Treasurer's salary and bond	115.97		
Sundries	42.77	161.04	
Total expenditures			$10 914.74
Transfer to invested funds			2 000.00
August 31, 1928 — Cash on hand			1 087.84
			$14 002.58

Invested Funds.

Invested funds September 1, 1927		$13 622.43
Paid to invested funds		2 000.00
Interest on bonds	$80.00	
Interest on deposits	62.04	
Interest on savings bank deposits	620.45	762.49
		$16 384.92
Interest paid over to the Association		$762.49
Invested funds August 31, 1928		15 622.43
		$16 384.92

The Finance Committee for the fiscal year ending August 31, 1928, recommended a budget of $10 600.00.

There has been expended during the year $10 914.74, an overdraft of $314.74. The details are as follows:

	Journal.	Office.	Meetings.	Miscellaneous.
Appropriation	$7 000.00	$2 600.00	$800.00	$200.00
Overdrawn	.....	308.95	5.79	.....
Transferred from	150.56	.....	.....	38.96
	$6 849.44	$2 908.95	$805.79	$161.04
Transferred to	.....	.....	189.52	.....
	$6 849.44	$2 908.95	$995.31	$161.04
Expended	6 849.44	2 908.95	995.31	161.04
Balance	.....	.....	.....	.....

Respectfully submitted,

ALBERT L. SAWYER, *Treasurer.*

TREASURER'S REPORT.

STATEMENT OF RECEIPTS AND EXPENDITURES.

Receipts.		*Expenditures.*	
Cash on hand September 1, 1927	$3 275.30	Bills paid as per vouchers	$10 914.74
Interest on bonds and deposits	762.49	Transfer to invested funds	2 000.00
Received from Secretary	9 964.79	Cash on hand August 31, 1928	1 087.84
	$14 002.58		$14 002.58

ASSETS AND LIABILITIES.

Assets.			*Liabilities.*	
Cash in banks as per list		$14 895.27	Surplus	$16 885.12
Old Colony Trust Co.	$1 087.84			$16 885.12
City Five Cents Savings Bank	2 000.00			
Farmers and Mechanics Savings Bank, Framingham	2 068.46			
Franklin Savings Bank	2 000.00			
Haverhill Savings Bank	2 000.00			
Home Savings Bank	1 011.25			
Mechanics Savings Bank	1 261.19			
Pentucket Savings Bank	2 000.00			
Peoples Savings Bank	1 466.53			
Bonds Nos. 2642 and 2644 Lake Shore & Michigan So. R.R. 4's due May 1, 1931		1 815.00		
Accounts Receivable		174.85		
Advertisements	$77.00			
JOURNALS	2.50			
Reprints	38.35			
Subscriptions	57.00			
		$16 885.12		

Annual Report of the Editor.

To the New England Water Works Association: The Editor submits herewith the following report for the year ending August 31, 1928.

As has been customary in the past, the tables of financial figures, accompanying the report, are based upon total charges and accounts receivable, rather than actual cash received or disbursed.

Table 1 is a statement of the material published.

Table 2 gives the receipts and expenditures for the year.

Table 3 is a comparison of the Journal for the past year with preceding years.

Size. The four issues contained 769 pages, of which 528 were text.

Cost. The gross cost of the Journal was $6 849.44 equivalent to $8.48 per member, and, the net cost was $1 716.25 equivalent to $2.12 per member.

Reprints. Fifty reprints of each paper have been furnished to the author where desired.

Circulation. The present circulation of the Journal is:

Members, all grades	808
Subscribers	132
Exchanges	15
Total	955

(Journals *have been sent to all subscribers.*)

Respectfully submitted,

GORDON M. FAIR, *Editor.*

EDITOR'S REPORT.

TABLE 1.

Statement of Material in September and December, 1927, and March and June, 1928, Issues of the Journal of the New England Water Works Association.

Date.	Pages of.								
	Papers.	Proceedings.	Total Text.	Index.	Advertisements.	Cover and Contents.	Insert Plates.	Total.	Total Cuts.
September, 1927	102	46	148	0	50	5	0	203	10
December, 1927	142	4	146	7	50	5	2	210	12
March, 1928	104	4	108	0	50	5	3	166	61
June, 1928	79	47	126	0	51	5	8	190	35
Total	427	101	528	7	201	20	13	769	118

TABLE 2.

RECEIPTS AND EXPENDITURES ON ACCOUNT OF SEPTEMBER AND DECEMBER, 1927, AND MARCH AND JUNE, 1928, ISSUES OF THE JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION.

Receipts.		*Expenditures.*	
Advertisements	$4 158.00	Reporting	$513.36
Subscriptions	518.98	Printing	3 913.97
Sale of JOURNALS	332.76	Plates	605.75
Sale of reprints	79.55	Mailing and postage	145.99
Sale of standard specifications	32.50	Reprints	887.20
Sale of filtration forms	3.60	Editor's salary	625.00*
Sale of meter rate sheets	2.80	Editor's incidentals	15.82
Sale of cuts	5.00	Advertising agent's salary and commissions	139.20
	$5 133.19	Sundries	3.15
Net cost of JOURNAL	1 716.25		$6 849.44
	$6 849.44		

*Includes June 1927 issue.

EDITOR'S REPORT.

TABLE 3.

COMPARISON OF JOURNALS OF THE NEW ENGLAND WATER WORKS ASSOCIATION.

	Vol. XXXII. 1918.	Vol. XXXIII. 1919	Vol. XXXIV. 1920.	Vol. XXXV. 1921.	Vol. XXXVI. 1922.	Fiscal Year Ending Aug. 31, 1924. 4 issues.	Fiscal Year Ending Aug. 31, 1925. 4 issues.	Fiscal Year Ending Aug. 31, 1926. 4 issues.	Fiscal Year Ending Aug. 31, 1927. 4 issues.	Fiscal Year Ending Aug. 31, 1928. 4 issues.
Average edition (copies printed)	1 388	1 200	1 130	1 150	1 100	1 100	1 100	1 100	1 100	1 138
Average membership	954	902	885	864	826	764	755	775	784	808
Circulation at end of year	1 010	1 002	970	929	929	880	873	906	916	955
Pages of text	398	566	359	399	618	404	421	523	492	528
Pages of text per 1 000 members	417	627	406	462	748	529	558	675	628	654
Total pages, all kinds	557	726	520	560	801	611	644	761	724	769
Total pages per 1 000 members	584	805	588	648	970	800	853	982	925	952
GROSS COST:										
Total	$3 115.00	$4 967.99	$5 011.03	$5 381.84	$6 354.10	$4 783.60	$5 272.91	$6 524.62	$5 839.36	$6 849.44
Per page	5.59	6.84	9.64	9.61	7.93	7.83	8.19	8.57	8.07	8.91
Per member	3.26	5.51	5.66	6.23	7.69	6.26	6.98	8.42	7.45	8.48
Per member per 1 000 pages	5.85	7.59	10.88	11.12	9.60	10.25	10.84	11.07	10.29	11.02
Per member per 1 000 pages text	8.19	9.74	15.77	15.61	12.47	15.50	16.58	16.10	15.13	16.06
NET COST:										
Total	$694.54	$2 675.04	$1 722.14	$1 869.85	$2 434.26	$561.51	$943.40	$2 040.28	$710.63	$1 716.25
Per page	1.25	3.68	3.31	3.34	3.04	0.92	1.46	2.68	.98	2.23
Per member	.73	2.97	1.95	2.16	2.95	0.74	1.25	2.64	.91	2.12
Per member per 1 000 pages	1.31	4.09	3.75	3.87	3.68	1.20	1.94	3.47	1.26	2.76
Per member per 1 000 pages text	1.83	5.25	5.43	5.43	4.77	1.82	2.97	5.05	1.85	4.02

Report of Finance Committee.

Executive Committee,
New England Water Works Association.

Gentlemen:

The Finance Committee has examined the books and accounts of the Secretary and Treasurer for the fiscal year ending August 31, 1928, and find them correct.

The Committee submits the following budget for the fiscal year ending August 31, 1929:

	Expended, 1927–1928.	Recommended, 1928–1929.
Journal	$6 849.44	$7 000
Office	2 908.95	3 400
Meetings and committees	995.31	1 000
Miscellaneous	161.04	*
Total	$10 914.70	$11 400

* Included under office.

The amount to be paid to The Affiliated Technical Societies of Boston for dues and charges as a member society for the year ending May 13, 1929, is $2 160, which is an increase of $160 over the last fiscal year.

Under office expenditures there is included $300 for printing the Constitution and List of Members.

The Finance Committee last year recommended and the Association approved a budget of $10 600. The Committee finds that there was expended during the year $10 914.74, an overdraft of $314.74. This was due to an increase in salaries voted by the Executive Committee and additional expenses in connection with the Convention at Montreal. We recommend that the act of the Executive Committee be approved by the Association.

Respectfully submitted,

SAMUEL E. KILLAM,
KARL R. KENNISON,
JOHN P. WENTWORTH.

PROGRESS REPORT ON "SPECIFICATIONS FOR CAST-IRON PIPE AND SPECIAL CASTINGS," "PIPE FLANGES AND FITTINGS" AND "MANHOLE FRAMES AND COVERS."

BY FRANK A. McINNES.*

I beg to make the following progress report on the status of the work of three Sectional Committees now engaged in formulating Standard Specifications under the authority and direction of the American Engineering Standards Committee, our Association being officially represented on each of these Committees.

Cast-iron Pipe and Special Castings.

The Third Annual Meeting of the Sectional Committee on Cast-iron Pipe and Special Castings was held in Washington, D.C., in March last, at which time the existing Officers and Executive Committee were continued for another term of two years.

The development of this Standard is being carried out by the Sectional Committee in a notably thorough and comprehensive manner through the agency of three Technical Committees and sixteen sub-committees.

Active work has, necessarily, been largely centered in the sub-committees, and time has not yet elapsed for definite results from these sou ees.

The following notes are of interest in connection with the : of the Committee. An executive assistant to the Chairman has been agreed upon, on the basis that one half of his time be employed by the American Water Works Association, and it is hoped that he will begin to function in the near future.

The 20-in. cast-iron pipes to be used in experiments at the University of Illinois on Talbot tests and at Iowa State College on trench-load tests have been delivered, and the experiments are now starting.

An investigation into the causes of corrosion of cast-iron pipe has been in progress at the Massachusetts Institute of Technology for some time past.

Pipe Flanges and Fittings.

The following Standards have been formulated by the Sectional Committee, approved by the American Engineering Standards Committee and published in pamphlet form.

Malleable-iron screwed fittings for 150 lb. W.S.P.; cast-iron screwed fittings for 125 lb. W.S.P., cast-iron screwed fittings for 250 lb. W.S.P., cast-steel pipe flanges and flanged fittings for 250 lb. W.S.P., cast-steel pipe flanges and flanged fittings for 400 lb. W.S.P., cast-steel pipe flanges and

*Chairman of the Committee.

flanged fittings for 600 lb. W.S.P., cast-steel pipe flanges and flanged fittings for 900 lb. W.S.P., cast-steel pipe flanges and flanged fittings for 1 350 lb. W.S.P., cast-iron pipe flanges and flanged fittings for 125 lb. W.S.P., cast-iron pipe flanges and flanged fittings for 250 lb. W.S.P.

Water ratings, in addition to the steam ratings mentioned, have been given in most of the above approved standards; it would appear that the water ratings of the cast-iron standards might be wisely reviewed, after the Sectional Committee on Cast-iron Pipe has completed its metallurgical studies.

The Standard for Cast-iron Long-turn Sprinkler Fittings is practically approved by the Sectional Committee.

The Standard for Cast-iron Flanges for pressures under 100 lb. was practically completed in June last and is now being reconsidered on certain points.

Work is in progress on the Standardization of Ammonia Fittings, Non-ferrous Screwed Fittings, Steel Flanges, Dimensions of Hubs of Loose Flanges, Hydraulic Cast-iron Pipe Flanges and Flanged Fittings for 800 lb. and Center to Face Dimensions of Ferrous Flanged-end Valves — Gate, Globe, Angle and Check Types,— with W.S.P. ratings of 125 lb. and 250 lb. per sq. in.

Manhole Frames and Covers.

The five sub-committees of the different fields to be covered have reported, and information received is being prepared for consideration by the Correlating Committee; it is expected that a meeting of this Committee will be held in the near future, at which time the various types and shapes of frames and covers that have been recommended by the sub-committees will be discussed, with a view to reduce their number to a minimum that will meet the various conditions of service, before they are considered by the entire Sectional Committee.

It is also intended, at this meeting, to consider means for placing information regarding the designs proposed before representative manufacturers and consumers in the United States, in order that constructive comments and suggestions may be obtained.

PROGRESS REPORT OF THE SECTIONAL COMMITTEE ON A CODE FOR PRESSURE PIPING.

BY MALCOLM PIRNIE.*

In the latter part of 1926, the American and New England Water Works associations were asked to coöperate with the American Society of Mechanical Engineers, acting as sponsors, for the development of a Code for Pressure Piping under the procedure of the American Engineering Standards Committee. At that time the writer was Secretary of the Standardization Council of the American Water Works Association and was asked by George W. Fuller, as Chairman, to sit in at the organization meeting as an observer.

My attendance at the first meeting, as the only representative of the water-works associations, resulted in my being appointed as Temporary Chairman of Sub-committee No. 3 on Hydraulic Piping. As my work during the past two years has necessitated my absence from New York a good share of the time, it has been impossible for me to serve in this capacity, and although the Chairman of the Committee on Committees was informed of this fact, there has been to this date no other representative of the water-works associations available to take my place.

It is hoped in the near future that the Committee on Water Works Practice, newly organized in the American Water Works Association, will be furnished with adequate technical assistance to handle the detail work of committees of this type and that, through such a provision, it will soon be possible for the water-works associations to do their full part in coöperation with other technical organizations in the excellent progress being made by the A.E.S.C.

*Chairman of the Committee.

PROGRESS REPORT OF REPRESENTATIVE AT TESTS OF THE BUREAU OF STANDARDS.

BY HARRY W. CLARK.*

As I stated to this Association last year, the Bureau of Standards has buried in different places all over the country, in nearly every State, 14 000 pipes of various kinds in different kinds of soil for studies of corrosion. From time to time they have taken up some of those pipes and examined them and photographed them. The Bureau has issued a publication in regard to the work which can be obtained by writing to Washington for it.

I was invited, as the representative of this Association, to join with a group last spring to travel around the country to see certain pipes taken up, but as that involved much time and considerable expenditure for travel, I did not think that I had the time or that this Association would care to pay for the trip after considering what might be gained from it.

The other day I received this letter:

DEPARTMENT OF COMMERCE.
Bureau of Standards.

Washington, September 4, 1928.

To Manufacturers and Technical Societies Coöperating with the Bureau of Standards in its Soil Corrosion Investigation.

Subject: Soil Corrosion Advisory Meeting.

Gentlemen:

1. During the spring and summer of 1928 specimens of lead cable sheath and ferrous pipe materials, buried in 1922, have been removed from 45 test locations. The losses of weight and depth of pits have been determined and specimens are now ready for inspection by those interested. To those desiring to make a detailed study of specimens, rating sheets will be furnished for grading each specimen according to the system adopted at the last soil corrosion conference. The corrosion data on each specimen will be furnished also.

2. You are invited to inspect the specimens at your convenience. We would appreciate a few days' notice of the time you would like to make the inspection but it will not be necessary to arrange in advance for this work.

3. On October 13, in Room 212, East building, we will hold our biennial soil corrosion advisory meeting. The purpose of the meeting is to discuss the report on the results of examining the 1928 specimens and on other soil corrosion work before it is made public. The rough draft of the report will be sent to you about October 1.

4. We wish your advice also concerning any additional soil corrosion work which you think should be undertaken for the purpose of verifying or extending the work now under way.

5. We would appreciate your being represented at this meeting. The attendance is limited to representatives of technical societies and manufacturers who have furnished pipe materials for the investigation.

Respectfully,

GEORGE K. BURGESS, *Director.*

*Representing the New England Water Works Association.

You see these studies are supposed to last ten years, with the 14 000 pipes buried in different kinds of soil. Only a certain number have been taken up, and data in regard to descriptions, etc., are so detailed that it is practically impossible as yet to make any summary of the work; in fact, I do not believe that any worth while summary can be made for several years to come. The Bureau is getting some data together, I believe, which will eventually be of great value.

REPORT OF COMMITTEE ON CEMENT-LINED PIPE.

September 18, 1928.

To the President and Members of the
New England Water Works Association,

Gentlemen: Pursuant to a resolution voted at the meeting of the Association, on March 8, 1927, the undersigned were appointed a committee to consider and report upon "The Effect of Cement-lined Pipes upon the Quality of the Water Supplied."

The precursor and, perhaps, the cause of the resolution was a paper read on the day of the resolution by Burton G. Philbrick of Boston*, describing certain experiences with cement-lined pipe in Quincy, Mass.

Mr. Philbrick noted a greasy, whitish scum on the surface of water in a tank supplied with Metropolitan water through a new cement-lined distribution-system. This scum consisted of crystals of calcium carbonate (chalk). The scum appeared during August, 1926, and disappeared before October.

At Danvers, a member of the Committee observed on one occasion that the hardness of the water supplied, as shown by analyses made by the State Department of Health, varied from 17 p.p.m. at the pumping station to about 80 p.p.m. at most of the taps and on one occasion reached 132 p.p.m. with a caustic alkalinity of 73 p.p.m.

New cement pipe exposed to the Danvers water lost calcium oxide quite rapidly at first and imparted caustic alkalinity to the water. This condition caused complaint, but was relieved by the gradual action of the free carbon dioxide in the water, changing the caustic into carbonate. It is to be expected that the cabonate will continue to be given off, increasing the hardness for an indefinitely long time, but finally decreasing in effect as the lining becomes coated with matter derived from the water itself.

Conditions at Danvers relative to these lined mains have been rather disagreeable in some instances. Water drawn from cement-lined pipes, particularly dead ends, is white with precipitated chalk; frequently chalky deposits are formed on agate kitchen-ware, while aluminum kitchen-ware is blackened, both occurrences following the heating of the water in the utensils. Frequently the water has a disagreeable odor and taste, probably due to fermentation of deposits. Samples of 4-in. and 8-in. cement-lined mains laid in 1926 and 1927, respectively, exhibited marked corrosion of the linings. These linings have the appearance of fine sandpaper, not of glossy new coatings.

Other members of the Association reported cases where cement linings were attacked by water to a noticeable degree.

*Jour. N. E. W. W. A., Vol. 41, p. 94.

At Leominster, W. Guy Classon has experienced considerable trouble due to cement linings. He submitted two samples of water from a dead end in the Leominster distribution-system, before and after flushing.

The results, which are quite striking, are shown in Table 1.

TABLE 1.

SHOWING EFFECT OF WATER ON CEMENT LININGS IN DEAD END, AT LEOMINSTER, MASS. Oct. 10, 1927.

Determination.	PARTS PER MILLION.	
	Before Flushing.	After Flushing.
Turbidity	120	20
Color	14	12
Alkalinity	281	88
Hardness	300	114
Total residue on evaporation	400	135
Mineral residue on evaporation	235	85
Hydrogen ion concentration, pH	8.4	8.4

It will be noticed that the turbidity, which is largely due to dissolved cement lining, was increased six fold by standing in the dead end. That this turbidity consisted of mineral matter is shown by the differences in alkalinity, hardness and mineral residue, all of which differ similarly.

At Milton, a member of the Committee collected a number of samples from various cement-lined services under conditions of ordinary use and standing over night, respectively. These services were supplied with Metropolitan water. Samples were analyzed, and the results are appended. The average, minimal and maximal increases in the various determined constituents, due to standing over night, are given in Table 2.

TABLE 2.

SHOWING EFFECT OF METROPOLITAN WATER ON CEMENT-LINED SERVICES AT MILTON, MASS.

Determination.	Average. p.p.m.	Maximal. p.p.m.	Minimal. p.p.m.
Turbidity	0.3	1.0	0.0
Color	1.3	3.0	0.0
Alkalinity	1.3	3.0	0.0
Total residue on evaporation	2.7	9.0	0.0

Quite high amounts of alkalinity and mineral matter were observed in samples from the Wendell Road, Wendell Park and Spencer services.

These results indicate that in the well-aged service there is some, but not much solvent action, but in new services, the action is considerable, — even great enough to impart a turbidity to the water.

At Taunton* analyses by the State Department of Health showed that the Taunton water increased in hardness from 10 p.p.m. to 80 p.p.m. in passing through 475 ft. of cement-lined service pipe.

Charles J. Crump, Superintendent of the Peabody Water Department, has kindly furnished the Committee with three samples, as follows:

No. 1 — from hydrant at end of cement-lined extension, after the water had been flowing through the hydrant 1.5 hours.

No. 2 — from end of cast-iron pipe.

No. 3 — from hydrant at end of cement-lined pipe.

The results of analyses of these samples, which were collected on November 7, 1928, are shown in Table 3.

TABLE 3.

SHOWING EFFECT OF WATER ON LINED AND UNLINED PIPES AT PEABODY, MASS.

Determination.	PARTS PER MILLION.		
	Sample 1.	Sample 2.	Sample 3.
Turbidity — silica standard	750	3	2
Color — platinum standard	17	23	12
Alkalinity	500	27	330
Hardness by soap method	97.2	31.2	343
Hydrogen ion concentration, pH	>8.4	6.9	>8.4
Iron	60.0	.....	.....
Total residue on evaporation	830	114	326
Total mineral residue	506	46	184
Carbonate alkalinity	100	.....	0.0
Bicarbonate alkalinity	400	.....	108
Caustic alkalinity	.....	.....	222

The large amount of mineral matter discharged from the cement-lined pipe, and the presence of caustic alkalinity in the discharge of the hydrant at the end of the line, are noticeable.

Effect of Aging. Your Committee thought it would be well to determine the effect of aging upon the new service. Accordingly, a 1-in. cement-lined service, 30 ft. long, kindly furnished by a prominent maker of cement-lined pipe, was installed and tested in the laboratory of Weston and Sampson†, supplied with water from the Boston mains. It was assumed that this typical service would discharge 250 gal. in 8 hours, and would stand idle for 16 hours on each calendar day. After a few preliminary trials, the service was so operated. Metropolitan water was allowed to stand in the pipe 16 hours and tested. The results obtained are shown in Table 4.

These increases were large. Subsequent tests, after various periods of use up to one year, indicated that some solid matters were dissolved from cement-lined pipe by Metropolitan water even under conditions of ordinary

*JOUR. N. E. W. W. A., Vol. 41, p. 95.
†At 14 Beacon St., Boston, Mass.

use, while amounts dissolved during a sixteen-hour period of standing were noticeable. How true this is may be seen from the plotted results of certain determinations shown in Fig. 1.

That the matters dissolved are highly alkaline is shown by the pH value, which was usually above 8.4 in the samples that had been in contact with cement lining.

TABLE 4.

RESULTS OF ACTION OF METROPOLITAN WATER ON NEW CEMENT-LINED PIPE.

Determination.	PARTS PER MILLION.	
	Metropolitan Water.	Test Sample.
Turbidity	5	20
Color	15	12
Alkalinity	16	1 520
Hardness	16.9	1 625
Total residue on evaporation	19	1 611
Mineral residue on evaporation	5	1 226

It will be noted that in these cases — in practice and in the laboratory — the water that attacked the cement was a surface water which was low in color and organic matter, soft, alkaline with sodium carbonate, and naturally low in carbon dioxide. No trouble has been reported where the waters are hard or are alkaline with calcium and magnesium bicarbonates. This observation conforms with practice in New England. Cement-lined services have been used mostly with waters that attack iron. These, for example, Waltham, Newton and Brookline, are hard compared with waters like the Leominster, Danvers and Metropolitan supplies, and contain calcium and magnesium bicarbonates. Many soft waters which might be supposed to attack cement-lined pipe contain enough peaty matter to form protective coatings on the insides of the service, thereby inhibiting solution of the cement.

Interesting in this connection are some long-time tests of briquettes of cement mortar, made by French engineers* in the laboratory of the *Société des Chaux et Cements de Lafarge et du Teil*, using six types of commercial cements.

The Director of the Laboratory, Etienne Rengade, reported that at the end of one hundred weeks of use the only cement to resist the action of distilled water was a high alumina cement, *ciment fondu*. On the other hand, ordinary river waters containing calcium and magnesium bicarbonates had no effect whatever.

The explanation of the difference in solubility is that ordinary cement sets with the formation of calcium silicate and calcium hydrate. The latter is soluble in distilled water or in a soft, clear water like the Metropolitan water, while in a somewhat harder water, containing bicarbonates and free

*Eng. News-Record, Vol. 100, p. 236.

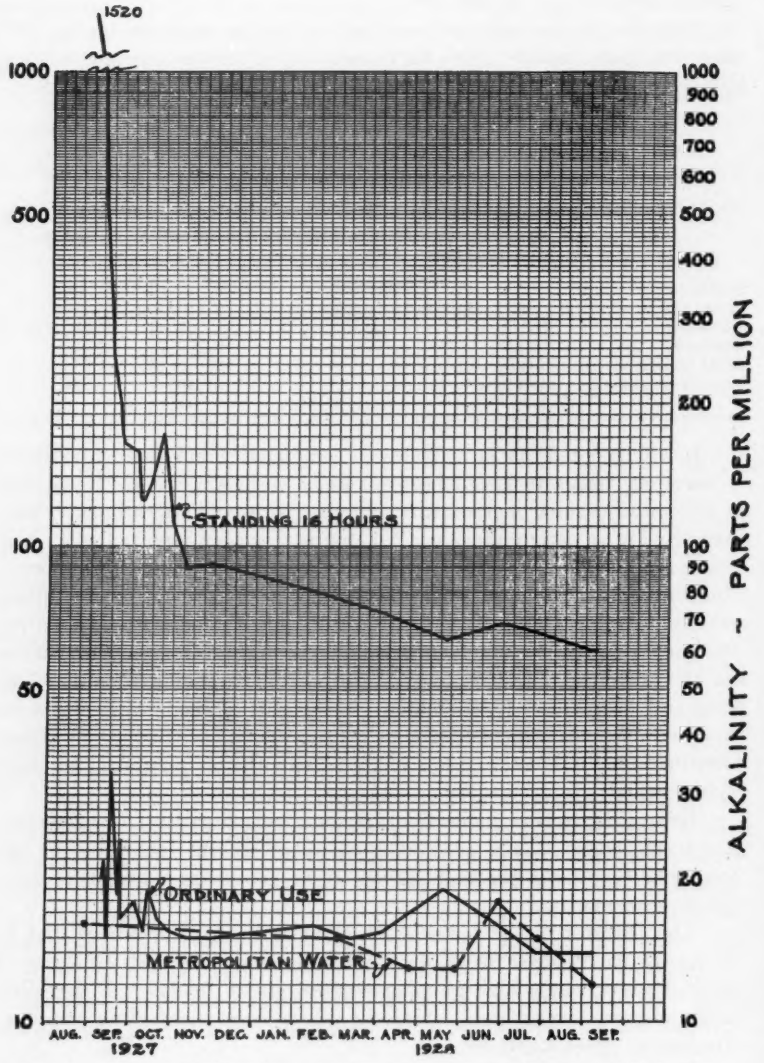

FIG. 1. — EFFECT OF METROPOLITAN WATER ON NEW CEMENT-LINED SERVICE.

carbon dioxide, the calcium hydrate in the cement is changed into calcium carbonate which is only slightly soluble. In the high alumina cements, slightly soluble aluminum hydrate is liberated in place of the soluble calcium hydrate.

The Worcester water is also interesting in this connection. Illustrations of services removed from the distribution system after more than sixty years of contact with this water, are shown in Fig. 2.

Hygienic Aspects. Primarily, the Committee was appointed to con-

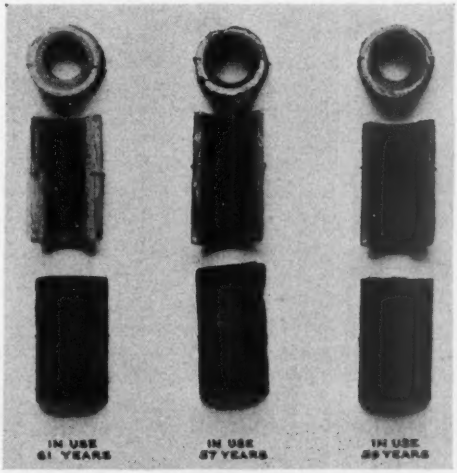

FIG. 2. — CONDITION OF CEMENT-LINED SERVICES AFTER ABOUT 60 YEARS OF USE, WORCESTER, MASS.

sider the hygienic aspects of the question, and its opinion regarding this is as follows:

The cement lining of a pipe consists entirely of minerals found in the earth which are also common constituents of water. Unlike lead and copper, they are not poisonous and, when present in such small amounts as were found, must be considered harmless.

To illustrate by a concrete example,— on February 15, 1928, the discharge from the experimental service under ordinary use, contained 60 p.p.m. of solid residue as compared with 55 p.p.m. in the Metropolitan water. This difference of 5 p.p.m. would be equivalent to 10 milligrams per diem, assuming 2 liters of water (about two quarts) to each person daily. Expressed in other terms, a daily ration of two quarts would contain only 0.15 grain of harmless salts. The insignificance of this may be realized when one compares the mineral salt contained in ordinary foods. For example, a tumbler of milk (250 cc.) contains about 1.8 grams of mineral matter. Therefore one would have to drink from a cement-lined service

two quarts of water daily for six months to ingest as much mineral matter as is contained in a tumblerful of milk. Futhermore, when one realizes that oatmeal contains 3 per cent. of mineral matter, and other foods more or less, the minuteness of the probable dose of minerals from cement linings in ordinary use is apparent.

Even in new pipe, where one might get a whole gram (15 grains) of solids, if the water first drawn were drunk exclusively, during the day — an unlikely condition, of course — the dose of mineral matter would be less

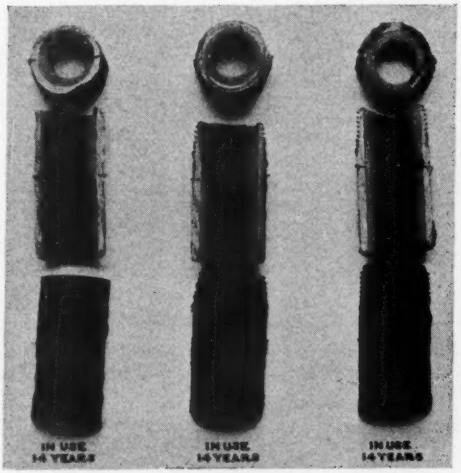

FIG. 3. — CONDITION OF CEMENT-LINED SERVICES AFTER 14 YEARS OF USE, MILTON, MASS.

than the amount taken by many an inhabitant of the middle West, drinking two quarts of hard well-water daily.

Economic Aspects. The hygienic side of the question being disposed of, there remains the economic side. If certain waters continue to dissolve cement lining, how long will they last?

Your Committee has collected numerous specimens of used services. Some of these, from Worcester and Milton, respectively, are illustrated in Figs. 2 and 3.

Practically all of these services have linings intact after many years. One specimen was in use for 63 years. The illustrations (Figs. 2 and 3) show more plainly than any description how durable are these cement linings.

Effect of Kind of Cement. While beyond its province, your Committee was led to make some other experiments to ascertain, if possible, what effect, if any, the kind of cement had upon the solubility of pipe linings in Metropolitan water and water typical of those types that dissolve cement.

The first experiment was with briquettes of Atlas, Lehigh, Lumnite and Rosendale cement. The briquettes were made by Skinner, Sherman and Esselen as if they were to be tested for tensile strength. The results of analyses are given in Table 5. The significant results are also shown in Fig. 4.

Apparently the high-aluminum cement possesses some advantages over ordinary Portland cement at the beginning, but the latter is less soluble afterwards.

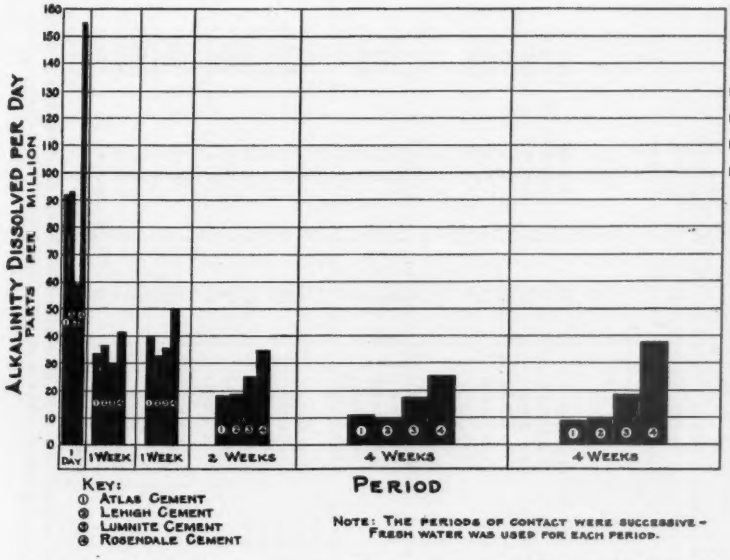

FIG. 4. — EFFECT OF METROPOLITAN WATER ON VARIOUS CEMENT BRIQUETTES.

Even in only a year, the experiments showed a decrease in the rate of solution, as Fig. 1 shows. In a service from a street, there would be more suspended matter to protect the cement lining than in a laboratory near the end of a plumbing system, where the tests were made.

The best evidences of the performances of cement lining are the evidences from practice, shown in Figs. 2 and 3.

Continuing along this line, samples of pipe and pipe linings that were furnished the Committee through the courtesy of various pipe manufacturers were tested. These pipes were filled with Metropolitan water and sealed for the period of tests. (Fig. 5.) The briquettes made with pipe-lining compound were tested like the cement briquettes, care being taken to have the ratio of volume of water to surface of cement lining the same in the test of the briquettes as in the test of the pipe.

The results of these tests are given in Tables 6 and 7.

TABLE 5.

EFFECT OF METROPOLITAN WATER ON VARIOUS CEMENTS.

Sample.	Time of Contact.	Turbidity.	pH Value.	Alkalinity.	Hardness.	Total Solids.
Metropolitan Water.	.....	3	7.2	13.0	20.8	75.0
Briquette No. 1 — Atlas Cement.	One day	3	>8.4	105.0	105.8	115.
	One week	3	>8.4	246.0	264.5	280.
Amount water used = 375 cc.	One week	3	>8.4	292.0	377.0	300.
	Two weeks	5	8.6	268.0	335.5	355.
Area of briquette = 106.45 sq. cm.	Four weeks	5	>8.4	320.0	351.0	460.
	Four weeks	5	>8.4	260.0	325.0	340.
Briquette No. 2 — Lehigh Cement.	One day	5	>8.4	106.0	108.6	160.
	One week	2	>8.4	268.0	300.0	320.
Amount water used = 375 cc.	One week	3	>8.4	240.0	325.0	330.
	Two weeks	1	8.6	272.0	585.0	340.
Area of briquette = 106.46 sq. cm.	Four weeks	5	>8.4	290.0	351.0	430.
	Four weeks	5	>8.4	280.0	325.0	330.
Briquette No. 3 — Lumnite Cement.	One day	5	7.7	72.0	67.6	160.
	One week	2	8.4	220.0	250.0	270.
Amount water used = 375 cc.	One week	5	>8.4	260.0	325.0	410.
	Two weeks	20	8.6	368.0	390.0	580.
Area of briquette = 106.46 sq. cm.	Four weeks	10	>8.4	500.0	529.0	830.
	Four weeks	5	>8.4	520.0	530.0	800.
Briquette No. 4 — Rosendale Cement.	One day	2	8.4	168.0	156.0	255.
	One week	2	>8.4	304.0	338.0	360.
Amount water used = 375 cc.	One week	2	>8.4	360.0	351.0	420.
	Two weeks	1	>8.4	500.0	650.0	605.
Area of briquette = 106.46 sq. cm.	Four weeks	12	>8.4	720.0	600.0	1 260.
	Four weeks	4	>8.4	1 060.	1 430.0	1 250.

NOTE. The periods of contact were successive. Fresh water was used for each period. Results are in parts per million.

TABLE 6.

EFFECT OF METROPOLITAN WATER ON VARIOUS CEMENTS FOR CEMENT-LINED PIPES.

Sample.	Time of Contact.	Color.	Turbidity.	pH Value.	Alkalinity.	Hardness.	Residue on Evaporation
Briquette No. 5 — Pipe Lining W.	One day	20	5	>8.4	266.	162.5	400.
	One week	10	1	>8.4	484.	600.	500.
Amount water used = 375 cc.	One week	10	3	>8.4	420.	429.	410.
Area of briquette, 106.46 sq. cm.	Two weeks	10	3	>8.4	380.	457.	500.
	Four weeks	7	25	>8.4	80.	111.	450.
	Four weeks	7	5	>8.4	360.	390.	420.
Briquette No. 6 — Pipe Lining U.	One day	20	4	>8.6	150.	130.	275.
	One week	10	10	>8.4	200.	221.5	305.
Amount water used = 800 cc.	One week	10	5	>8.4	160.	195.	240.
Area of briquette, 231 sq. cm.	Two weeks	8	10	>8.4	128.	143.	200.
	Four weeks	8	5	>8.4	114.	127.	300.
	Four weeks	5	3	>8.4	100.	52.	200.

TABLE 7.

EFFECT OF METROPOLITAN WATER ON VARIOUS CEMENT-LINED PIPES.

Sample.	Time of Contact.	Color.	Turbidity.	pH Value.	Alkalinity.	Hardness.	Residue on Evaporation.
6-in. Pipe — No. 7.	One day	35	2	8.5	66.	117.	475.
	One week	15	4	>8.4	180.	293.	420.
Amount water used = 5 200 cc.	One week	10	2	>8.4	192.	286.	290.
	Two weeks	10	10	>8.4	260.	271.5	350.
	Four weeks	5	3	>8.4	240.	351.	350.
	Four weeks	5	1	>8.4	228.	278.5	290.
6-in. Pipe — No. 8.	One day	20	5	>8.5	231.	224.	440.
	One week	10	3	>8.4	540.	571.	640.
Amount water used = 5 200 cc.	One week	10	8	>8.4	440.	520.	450.
	Two weeks	15	4	>8.4	424.	529	500.
	Four weeks	0	25	>8.4	510.	600.	670.
	Four weeks	2	1	>8.4	440.	600.	520.

NOTE. The periods of contact were successive. Fresh water was used for each period. Results are in parts per million.

TABLE 7 (*Continued*).

EFFECT OF METROPOLITAN WATER ON VARIOUS CEMENT-LINED PIPES.

Sample.	Time of Contact.	Color.	Turbidity.	pH Value.	Alkalinity.	Hardness.	Residue on Evaporation.
4-in. Pipe — No. 9.	One day	20	3	8.4	230.6	137.	225.
	One week	10	1	>8.4	420.	457.	580.
Amount water used = 2 100 cc.	One week	10	2	>8.4	240.	286.	220.
	Two weeks	..	2	>8.4	140.	138.	160.
	Four weeks	10	5	>8.4	86.	35.1	230.
	Four weeks	10	1	>8.4	92.	54.6	....
4-in. Pipe — No. 10.	One day	20	5	8.6	590.	201.5	830.
	One week	15	10	>8.4	560.	486.	680.
Amount water used = 2 100 cc.	One week	10	3	>8.4	440.	614.	480.
	Two weeks	8	5	>8.4	380.	457.	600.
	Four weeks	5	0	>8.4	330.	457.	440.
	Four weeks	10	40	>8.4	212.	264.5	400.
2-in. W. I. Pipe — No. 11.	One day	20	5	>8.4	625.	299.	1 085.
	One week	13	8	>8.4	970.	235.5	1 825.
Amount water used = 600 cc.	Two weeks	2	3	>8.4	580.	351.	980.
	Four weeks	0	3	>8.4	520.	457.	730.
1-in. W. I. Pipe — No. 13.	One day	18	25	>8.4	240.	325.	310.
	One week	18	10	>8.4	408.	416.	630.
Amount water used = 103 cc.	Two weeks	4	2	>8.4	520.	571.	720.
	Four weeks	8	10	>8.4	750.	1 235.	860.
	Four weeks	3	15	>8.4	110.	20.	250.
Metropolitan Water.	....	30	8	6.9	18.	19.5	50.

NOTE. The periods of contact were successive. Fresh water was used for each period. Results are in parts per million.

As expected, the various linings show considerable variations in solubility as indicated by Table 8.

There are great variations in the amounts of matter dissolved; the lining (No. 3) that gives the lowest alkalinity after one day does not give

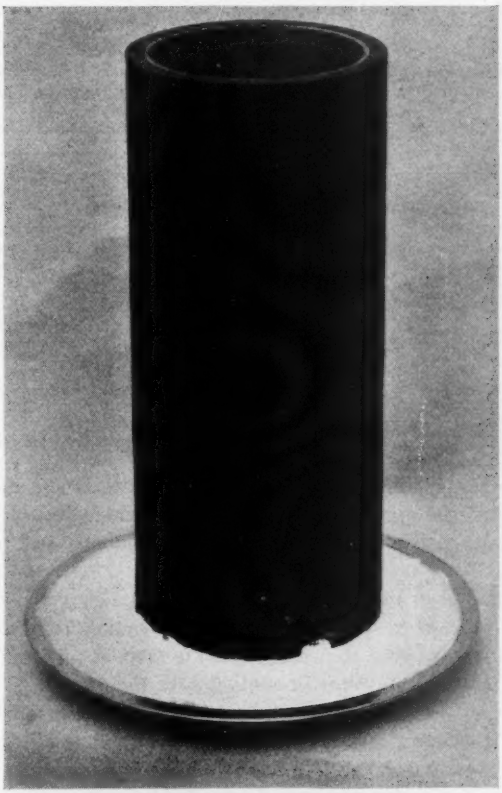

FIG. 5. — CEMENT-LINED PIPE SET UP FOR TEST.

the lowest per day during the last four of twelve weeks. Again, the lining (No. 5) that gives the lowest dissolved residue after one day does not give the lowest alkalinity. There are other apparent inconsistencies.

The best evidences of the performances of cement linings are the specimens of pipe shown in Figs. 2 and 3.

Incidentally the Committee tested a sample of pipe lined with a thick bituminous coating applied centrifugally. This lining was not appreciably dissolved by Metropolitan water, either after one day or after twelve weeks of contact.

Summary and Conclusions. While it is true that certain waters attack cement-pipe linings and cause water of disagreeable appearance to be drawn, these occurrences have no hygienic significance.

While the amounts of the cement lining dissolved are considerable, the rate of solution lessens with the years. Experience in practice indicates a long life for cement-lined services. A long life for proper cement linings

TABLE 8.

SHOWING AMOUNTS OF ALKALINITY AND RESIDUE ON EVAPORATION DISSOLVED FROM PIPE LININGS PER DAY AFTER FIRST DAY AND LAST FOUR OF TWELVE WEEKS RESPECTIVELY.

Lining No.	After First Day.		After Last Four of Twelve Weeks.	
	Alkalinity. p.p.m.	Residue on Evaporation. p.p.m.	Alkalinity. p.p.m.	Residue on Evaporation. p.p.m.
1	246	350	12.1	13.2
2	130	225	2.9	5.4
3	46	425	7.4	8.6
4	211	390	15.0	16.8
5	211	175	2.6	....
6	570	780	6.8	12.5
7	605	1 035	15.0	18.5
8	220	260	3.2	7.1

in cast-iron pipes is indicated by the experience with cement-lined services.

Apparently, the only waters that dissolve cement linings appreciably are soft surface waters containing alkaline carbonate and little carbon dioxide.

Great differences in the solubility of pipe linings were shown by experience. This leads to suggesting that pipe manufacturers consider carefully the relation between the composition of cement-pipe linings and the character of the water to come in contact with them.

It is suggested that where the action of a water upon cement linings is troublesome, the water may be treated chemically at small expense to reduce its solvent action. The practicability of indurating the cement linings at the pipe works by chemical treatment before shipment is suggested for consideration.

Acknowledgments. In conclusion the Committee wishes to thank the Warren Pipe and Foundry Company, the U. S. Cast Iron Pipe and Foundry Company, the National Cast Iron Pipe Company, the Cement Lined Iron Pipe Co., and the National Tube Company, for specimens of pipe and pipe linings and for coöperation and advice during the investigation.

Respectfully submitted,

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